Welcome to ACES

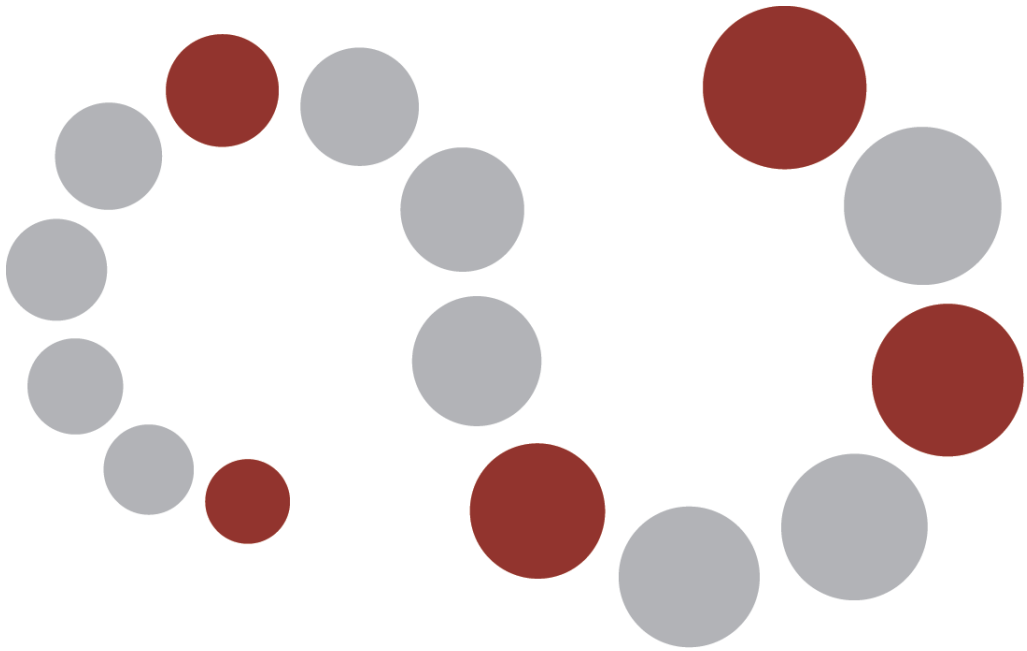
ACES is the Australian Research Council (ARC) Centre of Excellence for Electromaterials Science. It was established to bring together eminent scientists to develop the nano-science and nano-technology related to the movement of electric charge within and between materials. These processes are fundamentally 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 materials in biomedicine, corrosion protection, energy harvesting and energy storage.

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 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.

ACES is 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 Vincent's Health in Melbourne.

ACES was established in 2005 and is funded by the ARC with $12 million in federal funding over five years. ACES also receives support from the NSW Department of State & Regional Development to achieve technology transfer to NSW and Australian industry.

This 2006 Annual Report is a part of the Centre's reporting requirements and sets out the Centre's achievements for the 2006 calendar year. It reports on the progress made by the Centre's four main research programs: Electromaterials (P1), Energy conversion (P2), Energy storage (P3) and Bionics (P4). It also discusses progress in several other areas in which the Centre is active (such as ethics, education and outreach).



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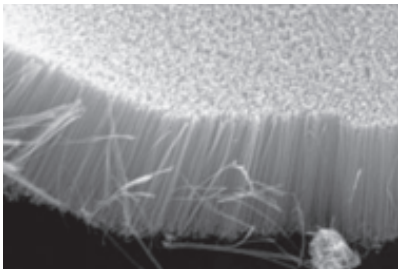
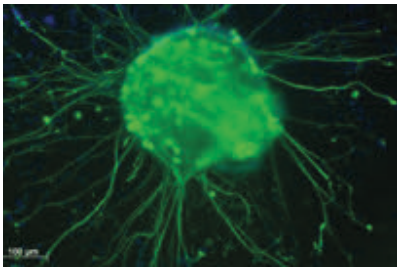
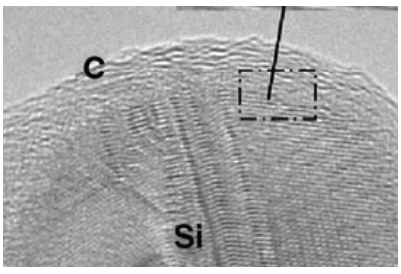
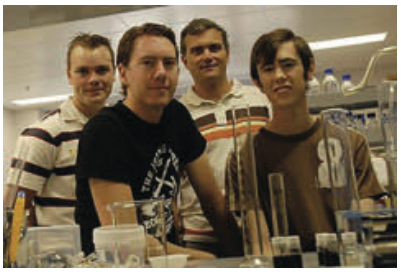








Appendices

From the Research Director

I hope you will agree that this report on our activities in 2006 describes an exciting period in the development of our Centre.

Research in our core programs has been consolidated and exciting new opportunities have been identified as individuals have embraced this exciting new arena in which we are privileged to work. Our Education and Training programs have been established as have the mechanisms that we will use to disseminate our findings to the wider scientific community, the commercial sector and the public in general. Our international profile has been consolidated through the formation of additional strategic linkages, a vibrant publication drive and invitations to present at international events.

Our greatest achievement during 2006 has been to build teams of individuals capable of delivering on these challenging goals. We continue to attract top researchers from around the globe to be part of our endeavours. Twenty-four scientists from eight countries worked in our laboratories during 2006. In addition, a number of excellent academic staff members, research fellows and PhD students were attracted from around the world to join ACES during this past year.

Our administrative staff are of the highest calibre and their unwavering support has been critical in the formative stages of ACES. Staff from all four host institutions (in areas such as Offices of Research, DVCs/PVCs research, personnel, finance, buildings and grounds and other important areas) have embraced ACES and worked tirelessly to help us establish a brilliant team of individuals with the infrastructure needed to make a significant impact.

Our collaborative research network continues to grow in strength. We are indebted to individuals within the companies, Cooperative Research Centres and other research organizations who work with us on a daily basis in the pursuit of diverse and exciting research goals.

I am also grateful to our International Advisory Board. This group of individuals, while meeting formally once per year, have provided continuous input and advice to ACES at all levels. Towards the end of 2006 the End Users Committee was established – thank you to those individuals who agreed to assist – 2007 should be an exciting year!

It is no accident that my report for 2006 focuses on the people that comprise ACES – they are by far our greatest and most valuable resource. They have created the physical environment that enables great ideas to move forward. We have already achieved some important strategic milestones as part of ACES and I feel certain 2007 will be an even more productive year.

On a personal note I am indebted to all of my friends and colleagues who have worked with us over the years and enabled us to obtain an ARC Federation Fellowship in 2006. The Fellowship enables us to build upon the ARC Centre's Bionics program with an immediate impact by providing new resources into the NanoBionics area.

I look forward to 2007 – we have an exciting program of research, education and Training and Outreach to undertake. As was the case in 2006, we will rely on many new and old research friends to meet our goals.

We are indeed fortunate to be scientists working in this exciting area of research – I think I can safely say that next year's research highlights will contain findings that we can not yet imagine here in January 2007!

I hope you enjoy reading our Annual Report.

Professor Gordon G. Wallace

Executive Research Director
ARC Centre of Excellence for Electromaterials Science

"the people that comprise ACES are by far our greatest and most valuable resource."

International Advisory Board's report

On the 7th of February 2007 the International Advisory Board reviewed the progress of ACES during 2006. Those in attendance were: Prof Ray Baughman (Acting Chair), Prof Siegmar Roth, Prof Andrew Holmes, Dr Greg Smith, Prof Margaret Sheil, Prof. Peter Robinson, Prof. Richard Kaner, Dr Abid Khan, Prof. Naoya Ogata and Prof Mark Cook. The Board was unanimously impressed by the quality and quantity of work achieved by the Centre. The significant outcomes for the year are summarized below.

The Science - Highlights

Core programs, such as organic synthesis and use of conductive electroactive polymer (CEP) dopants (PMAS), are being fed into the Bionics area; e.g. nerve cells and spinal cord regeneration. Activities include muscle regeneration with Rob Kapsa, stents with Boston Scientific, and epilepsy with Mark Cook.

Device fabrication techniques were developed; such as inkjet printing, screen printing and use of a research grade Dimatix printer, wet-spinning of carbon nanotubes (CNT) biofibres using a research grade spinning machine, and the Atomate chemical vapour deposition (CVD) equipment for synthesising aligned carbon nanotubes (CNTs) that can be used for new bio-structures or new flexible CNT electrodes (patents lodged).

Biocompatible battery using an ionic liquid, a Mg anode and a CEP cathode was developed (provisional patent is to be lodged).

Vapour phase polymerization (VPP) to synthesise CEPs such as PEDOT using Fe(III) salts with different ligands was developed. Thin films have been formed with conductivities >1000S/cm (e.g. PEDOT-pTS).

Flexible PEDOT-MSA film (0.5 mm thick) formed on PET conducted a maximum current density of up to 12,000 A/cm2.

Frontier scientific research has been performed in areas that are of national and international relevance and significance, especially where nanoscience and nanotechnology play a role. Advances in the Programs of Energy Conversion and Energy Storage (such as solar cells, artificial muscles, and lithium batteries), and the Bionics Program (such as nerve cells regeneration and growth) will have a major impact on the international scene.

The International Profile

During 2006, ACES hosted a significant number of visitors of whom 73 were from overseas; including those from China, Korea, Ireland, Japan, UK, USA, Canada, Denmark, Switzerland, France, New Zealand, Thailand, Netherlands, Italy, Sweden, India, Germany, and Saudi Arabia. ACES initiated or consolidated collaborations with these visitors including: Prof Dermot Diamond from Dublin City University, Ireland; Prof Richard (Ric) Kaner from the University of California Los Angeles, USA; Dr Mahendra Shirsat from the Dr Babasaheb Ambedkar Marathwada University, India; Prof Seon Jeong Kim, Hanyang University, Korea; Prof Jang Myoun Ko, Hanbat National University, Korea; Prof Gyou-Jin Cho, Sunchon National University, Korea; and Prof Zi-Feng Ma, Shanghai Jiao Tong University, China. Memoranda of Understanding have been signed with these counterparts in Korea and China.

In addition to hosting a range of visitors, ACES personnel were invited to visit leading international laboratories such as in China, USA, Sweden, UK, Korea, Japan, Finland, and Switzerland.

Twenty-three invitations were accepted by ACES personnel to address conferences of which 18 were international. These include: Professor Doug MacFarlane at the 15th International Symposium on Non-oxide Glasses in India; Professor Graeme Clark as a Prominent Speaker at the 37th Nobel Mini-Symposium, Frontiers in Medicine at the Karolinska Institutet, Stockholm, Sweden; Professor Maria Forsyth at the American Chemical Society National Meeting in San Francisco, USA; and Prof Gordon Wallace as a Plenary Speaker at the World Congress on Medical Physics and Biomedical Engineering, Seoul, Korea.

The Educational Environment

This Centre maintains a vibrant and happy environment for educating and training postgraduate students (27 PhD, 2 undergraduate and 3 intern students). Training workshops were held from 13 to 15 February 2006 followed by the Inaugural International Symposium on Electromaterials Science at the University of Wollongong; held between 15 to 17 February 2006. A full Centre meeting was held on the 10th-11th of May 2006 at the Monash Science Centre in Melbourne. In addition, two Ethics and Regulation Workshops were held at the University of Wollongong on 23rd August 2006 and at Monash University on 30th August 2006.

The Centre offered 11 Summer Scholarships to undergraduate students during the 2005-2006 Summer (5 at Wollongong, 6 at Monash).

Outreach

Innovation Week unfolded at the University of Wollongong the week beginning Friday 5th May 2006, with the Innovation Week public lecture delivered by the Executive Research Director of ACES, Professor Gordon Wallace. This was followed by public laboratory tours of the IPRI node of ACES.

During 2006, the activities of ACES personnel attracted media attention: 21 in print, 2 website, 8 radio, and 5 TV. For example, Prof Graeme Clark had media coverage by: Cosmos Magazine, Radio National, Channel 10, Wealth Creator Magazine, ABC Canberra, Bulletin, and Herald Sun.

"All of the Key Performance Measures have either been met or exceeded"

As part of the outreach program of the Centre, Prof Maria Forsyth and PhD student Nolene Byrne from Monash University presented an "Electromaterials in Action" demonstration and talk to students at local Schools in Victoria. In addition, IPRI PhD students Brianna Thompson and Jenny Halldorsson were awarded Young Science Ambassadors Awards grants from the Australian Research Council Nanotechnology Network to visit high school students in the local area, with the aim of inspiring students about nanotechnology and promoting science education.

Six schools in the Illawarra Region were visited as a part of the ARCNN Young Ambassador's program. The schools were chosen so that a cross section of the community was represented, with students from differing socio-economic backgrounds as well as varying age groups addressed. The groups of students included four Year 9 classes and four Year 12 classes, and as such, a variety of students at different levels were exposed to the presentation.

Non-Centre Funding

Non-Centre funding was obtained, for example as follows:-

Energy Conversion Program – ARC Linkage grant with Schefenacker Vision Systems, and CRC Polymers funding.

Energy Storage Program – CRC SmartPrint, and Cap-XX funding.

Bionics Program – Bionics Australia, Boston Scientific, and NCRIS funding.

Key Result Areas and Performance Measures

All of the Key Performance Measures have either been met or exceeded. For example, the target for 2006 publications was 30 refereed publications of which at least 15 would have an impact factor greater than 2. The outcome has greatly exceeded these targets with a final result of 61 refereed publications of which 33 have an impact factor greater than 2.

Prof Ray Baughman

Acting Chair

International Advisory Board for ACES

At the meeting in February, 2007, ACES welcomes to the IAB Professor Mark Cook and Dr Abid Khan.

Research highlights

A full milestones report for Year 1 is given under the 2006 Activity Report. Progress towards other milestones are in Appendix I. Highlights for 2006 are described here.

Program 1: Electromaterials

The Electromaterials Program underpins the strategic research efforts of ACES. Working with colleagues involved in the other three science research programs (Energy Conversion, Storage and Bionics), specific needs for improvement in electromaterials are identified and innovative synthetic as well as material fabrication methods are developed to meet the challenges.

As well as producing new monomers such as the thiophenes (Fig. 1) – new synthesis approaches enabling production of nanostructured Inherently Conducting Polymers (ICPs) have been developed. For example, we have found that unique nanofibrillar structures of polypyrroles or polythiophenes are produced when ionic liquids are used as the reaction media. We have also adapted Kaner's nanofibre synthesis protocols to produce unique nanostructured material with polyaniline as the backbone and with a sulfonated polyaniline dopant. Such stable nanodispersions provide a new gateway to processability. For example, nanoparticles based on polyaniline have proven to be suitable for inkjet printing of novel electrodes for sensors or electrochromic devices.

We have also (finally) been successful in developing simple and reliable approaches that allow covalent attachment of functional groups to carbon nanotubes. The functionalised materials produced have been shown to act as unique electronically conducting polyelectrolyte dopants in conducting polymers.

Our carbon nanotube production capabilities have been upgraded with acquisition of a fully automated CVD system from Atomate. Aligned carbon nanotube mats of controlled tube length and density are now routinely available.

One of the most exciting advances during 2006 has been in the area of wet spinning of organic conducting fibres. We have established the use of biomolecules as both dispersant and coagulant during the spinning process.

"Inevitably the electromaterials program provides the significant odd discovery that lights up the eyes of our colleagues in these other programs as they immediately identify opportunities."

For example, the use of hyaluronic acid as dispersant and chitosan as coagulant results in the formation of CNT biofibres (Fig. 2) with an exceptional combination of both conductivity and mechanical properties. It is envisaged that these structures will find application in the Bionics program as unique conduits for nerve regrowth.

These same dispersions have also been used to produce bioelectrodes (by vacuum filtration) with amazing strength and conductivity. We discovered that simple casting of these formulations results in production of bio gel electrodes. A novel fabrication protocol was introduced to us by Prof Ric Kaner (UCLA). This involves flash welding of organic conducting nanostructures and has been used by us to produce novel artificial muscle configurations based on polyaniline nanostructures.

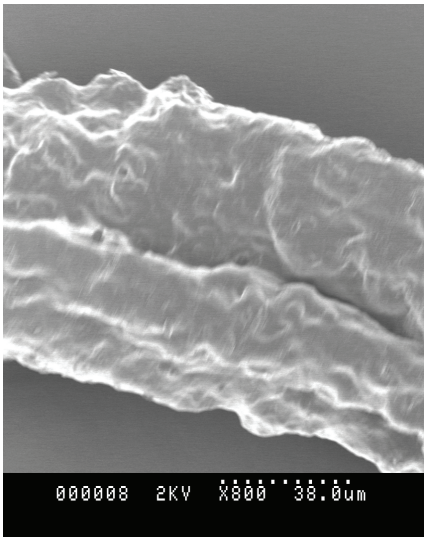
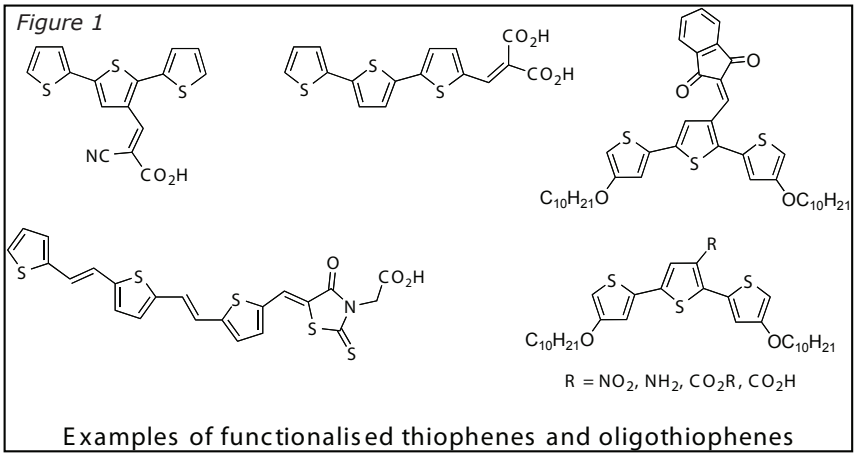


Figure 2: Scanning electron micrograph of a carbon nanotube bio-fibre (Hyaluronic acid-SWNT- Chitosan).

Wet spinning techniques have also been used to produce PAn Carbon NanoTubes (CNTs) in a single step. Fibres with a combination of the highest strength and conductivity reported to date have been produced. These fibres have been used to produce "Super" artificial muscles.

Figure 1



Examples of functionalised thiophenes and oligothiophenes

Synthesis of inorganic nanoparticles in ionic liquids has proven an extremely useful approach (Fig. 3). These quantum dots are of interest as opto-electrochemical materials since fluorescent properties are size dependent and surface charge dependent. The ionic liquid solvent allows the introduction of a much wider range of surface decorating groups to allow attachment to electrodes and to control the fluorescence wavelengths.

We continue to improve the inventory of characterization tools available and the training needed to run them

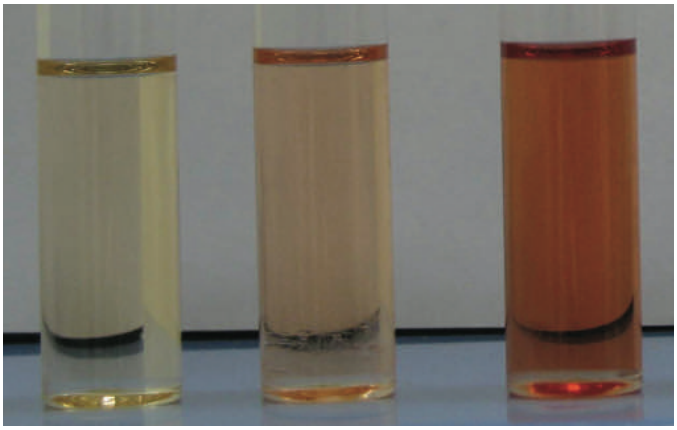


Figure 3: CdSe quantum dots in an ionic liquid medium showing the size dependence of fluorescence.

for Centre members and Associates. During 2006 we have acquired, installed and provided training on a Scanning Electrochemical Microscope (with the support of BlueScope Steel). We have also acquired a solar simulator with associated facilities for rigorous solar cell testing with the support of the CRC Polymers. Fourier Transform AC Voltammetry - a technique pioneered by one of our Associate members (Prof A. Bond) has been introduced to ACES staff and students.

Along with significant achievements in our strategic milestones there have been numerous "non core" discoveries during 2006. For example, we observed that hydrogels that expand when immersed in acid were found to shrink when the gel was exposed to acid and when the gel was subjected to a constant compressive stress (*Nature Materials* 2006). This unusual and unexpected behaviour is important in gel actuator devices such as valves, where a compressive stress is produced by the surrounding fluid pressure. The surprising shrinkage was linked to changes in the gel properties and particularly the surface friction which allowed the compressive stress to be more efficiently applied in the acidified state.

Program 2: Energy Conversion

The focus of the Energy Conversion Program remains in the development of (flexible) organic solar cells and in improved performance artificial muscles.

Plastic Solar Cells

Improved dye molecules based on porphyrins have been produced and resulted in improved performance in TiO_2 based cells. Of particular note are the malonic acid porphyrins and the new benzoic acid porphyrins (Fig.4).

A flexible solar cell has been produced. This uses flexible TiO_2 electrodes and a plastic solid electrolyte (Fig. 5). Efficiencies around 1% have been realised.

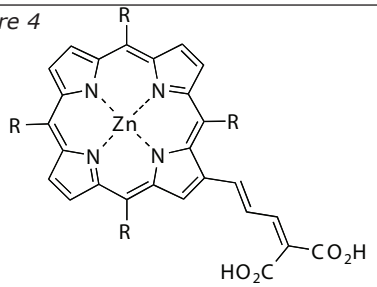
Electromechanical Actuators

The Centre aims to develop the technology of electromechanical actuators by developing novel nano-structured electromaterials. Our ultimate aim is to produce a low-voltage actuator that can produce the same mix of movement, force and speed as generated by natural muscle. In the first two areas, certain formulations of conducting polymers match the performance of muscle but we still fail to reach the speed of response (full contraction in 0.1 sec) that muscle achieves. Our strategy is to mimic the detailed nanostructure of muscle in our artificial muscle systems, so as to improve the speed of response while maintaining large movements and force outputs.

The past year has seen the publication of several important papers that demonstrate significant breakthroughs achieved by Centre staff and collaborators:

- Demonstration of ultra-fast stress response in carbon nanotube sheets (*Advanced Materials* with John Madden, University of British Columbia and Ray Baughman, University of Texas at Dallas).
- Development of the fastest conducting polymer bending actuators (*Synthetic Metals*).
- Better understanding of the complex (and surprising) interaction between gel actuators and the external mechanical systems (*Nature Materials* with Seon Jeong Kim, Hanyang University).
- Development of nanostructured polyaniline fibres that show actuation at the highest stress yet reported (*Advanced Materials*).
- First demonstration of higher actuation performance at higher operating stresses in polythiophene actuators (*Polymer*).

Figure 4



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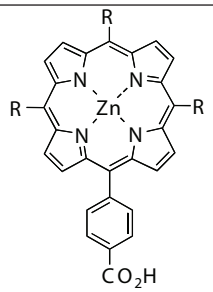
Malonic acid porphyrin derivatives



R = Ph, tolyl, xylyl, mesityl

Benzoic acid porphyrin derivatives

Research highlights

"We know that if we can produce an artificial muscle that works as well as natural muscle, there will be dozens of applications in machine parts, robotics and the biomedical field."

These developments in materials also impact on the actuator modeling program (P1-3) such that new, improved actuator materials are provided to the modeling researchers.

We continue to develop a better understanding of the complex processes occurring from the molecular to the macroscopic scale that determines the performance of artificial muscles. This improved understanding allows us to engineer the structure of the materials at the nanoscale so as to improve their performance as actuators.

Figure 5: Example of flexible dye-sensitised solar cells based on a plastic solid electrolyte material and TiO_2.

Program 3: Energy Storage

All Solid-State Thin-Film Lithium-Ion Microbatteries

Highly reversible lithium storage has been achieved in spheroidal carbon-coated silicon nanocomposites used as anodes in lithium-ion batteries.

These TEM images (Fig. 6) show spheroidal carbon-coated Si nanocomposites produced by spray pyrolysis in air: (a) low-magnification image of a sample produced at 400^{O}C, with the indexed diffraction pattern (inset) confirming the presence of Si nanoparticles; (b) high-resolution image showing the carbon-coated Si nanocomposite, with the inset showing the interface between a crystalline Si particle and the pyrolyzed carbon coating layer (ca. 10 nm thickness).

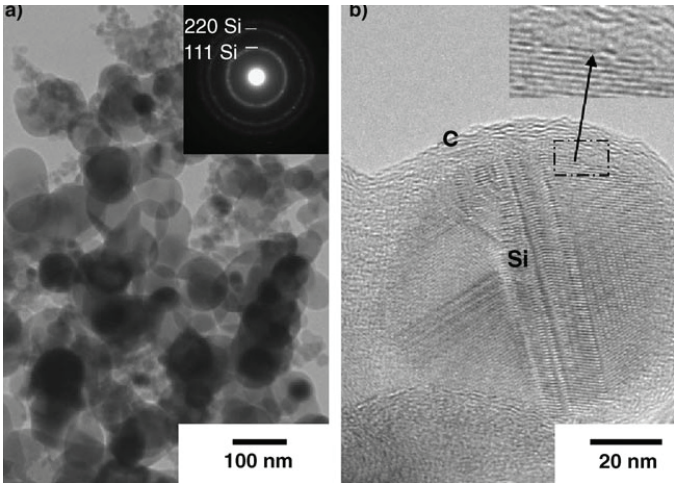


Figure 6: From See-How Ng, Jiazhao Wang, David Wexler, Konstantin Konstantinov, Zai-Ping Guo and Hua-Kun Liu, Angewandte Chemie International Edition*, 45 (2006) 6896-6899.*

Nano-composite electrolyte materials for organic batteries have been prepared and shown to exhibit large nano space charge effects which enhance conductivity by as much as two orders of magnitude.

"In all of the areas of our energy storage research, new materials are emerging which will provide breakthrough performance in the energy storage devices that we will be building later in the program."

Advanced (Metal) Batteries

A new class of biocompatible organic/inorganic batteries has been designed for in-vivo use. Initial tests show promising results (Fig. 7). The batteries contain a metallic anode of magnesium or magnesium alloy, a conducting polymer cathode and an ionic liquid electrolyte. All of the materials are chosen to be biocompatible and eventually biodegradable.

Organic Batteries

Polythiophene based materials have been evaluated as electrodes with a view to producing an all-polymer battery. Functionalised polythiophenes used as the anode in a Li ion battery have demonstrated capacities of upto 94 mA.h.g^{-1}.

In another advance, charge carrier "super-mobility" has been discovered in vapour phase polymerised PEDOT materials (Fig. 8). These have potential to be optimal conducting polymer materials for organic battery and super-capacitor applications.

Figure 8: A PEDOT polymer coating on a standard PET-foil (multimeter shows Ohms).

Figure 7: A prototype cell under test; cell voltage read by the voltmeter is 1.45 Volts.

Research highlights

Program 4: Bionics

The Bionics program aims at determining the factors that facilitate the transfer of electrical energy such as between an electroactive polymer and the body, and in particular the nerves. This research is being directed towards a new generation of cochlear implants for deafness, and spinal cord scaffolds to provide a functional link across a damaged section of the cord.

Improving the nerve-electrode interface of the cochlear implant using polymer technology

The cochlear implant stimulates hearing nerves in the inner ear after deafness helping profoundly deaf people to communicate. But in many cases, deafness can cause hearing nerves to degenerate. Our aim is to preserve as many hearing nerves as we possibly can to ensure that the cochlear implant can work to the best of its ability.

Achievements

To preserve and regrow nerves in the inner ear after hearing loss, we sought a polymer coating for the implant that stores and releases nerve growth factors, conducts the electrical signals to the hearing nerves and encourages the nerves to grow directly on the implant electrodes.

We conducted extensive research into the capacity of polypyrrole to store and release nerve growth factors. We discovered that it can store nerve growth factors in quantities that are comparable with nerve survival and regrowth in the inner ear. It was then shown that electrical stimulation could be used to switch the release of nerve growth factors on or off as desired, with only minor leakage of nerve growth factors from the polypyrrole structure in between stimulation.

We also discovered that when the polymer had nerve growth factors incorporated into its structure, nerve outgrowth was encouraged. This is an important and exciting result as it means the polymer can be used to preserve the hearing nerve. We discovered that the polymer is promoting nerve survival and nerve outgrowth through the low-level natural diffusion of nerve growth factor from its structure (Fig. 9).

We were interested in how the hearing nerves were adhering and growing over the polypyrrole surface so we used electron microscopy to examine the fine structure of nerves growing on polypyrrole. Under very high magnification, the surface of polypyrrole appeared nodular. However, the bumpy surface did not discourage nerves growing on polypyrrole. We found that nerves were equally happy to grow on the surface of polypyrrole as they were to grow on other cells or other surfaces (Fig. 10).

"Over the next few years we will be conducting studies to determine whether a polypyrrole-coated cochlear implant can preserve and regenerate auditory nerves in a deafened animal."

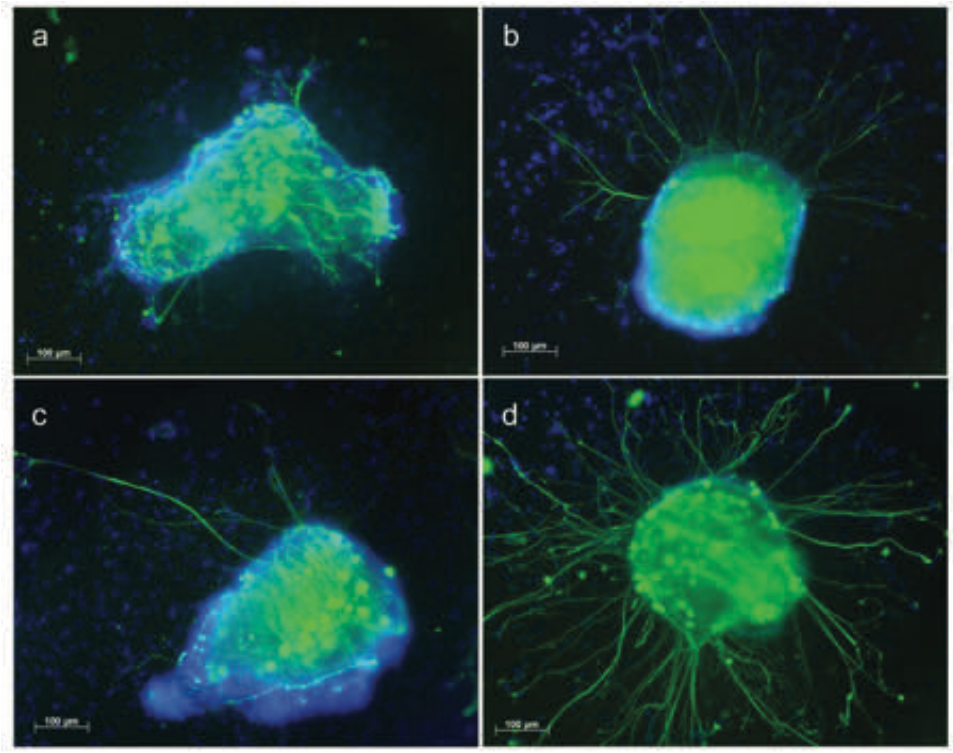


Figure 9: Inner ear nerve tissue grown on plain polypyrrole shows poor nerve outgrowth (a). A coating of cell adhesion molecules to plain polypyrrole (b) or incorporation of NT3 into the polymer (c) improves nerve outgrowth from the tissue. However, more extensive nerve growth is observed when nerve growth factors are incorporated into polypyrrole and a cell adhesion coating is applied (d).

Creation of a polymer surface to enable regeneration of injured spinal neurons

As injured spinal neurons do not regrow spontaneously, it is necessary to modify their environment by providing nerve growth factors (neurotrophins) and surface adhesion molecules (laminin) to help them grow and re-establish connections with other neurons. Polypyrrole is of great interest because as a conducting polymer, bioactive molecules can be incorporated into and released from its internal structure using electrical current. This means that neurons growing along the polymer surface can be exposed to appropriate quantities of neurotrophins released from the polymer in a highly controlled way. However, the surface of the substrate can significantly influence the amount and pattern of axonal growth. To see if polypyrrole could produce neuronal growth similar to that seen on glass we made films with a number of different molecular dopants. Each dopant molecule confers a unique chemical and morphological (shape) profile to the surface. Nerve cells were then placed onto each of the different films that were previously coated with the neuronal adhesion molecule laminin (Fig. 11).

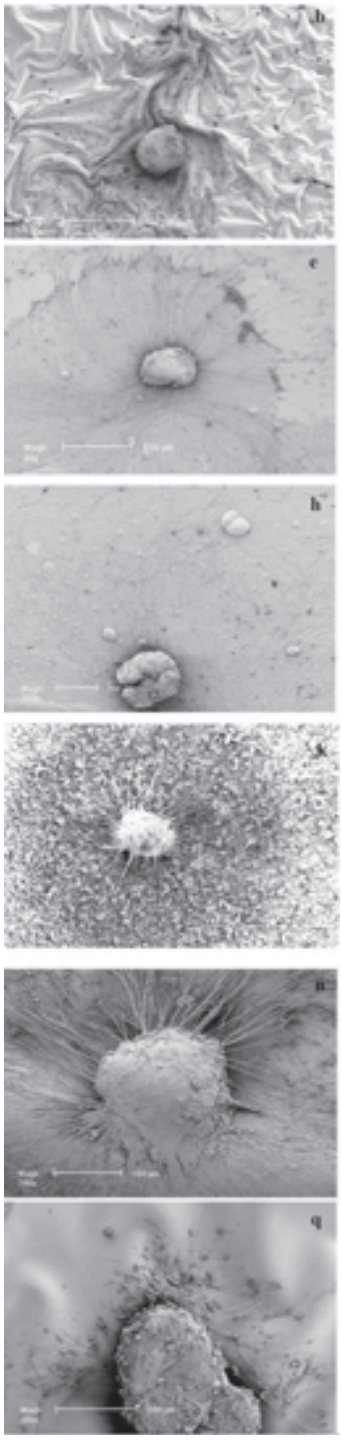
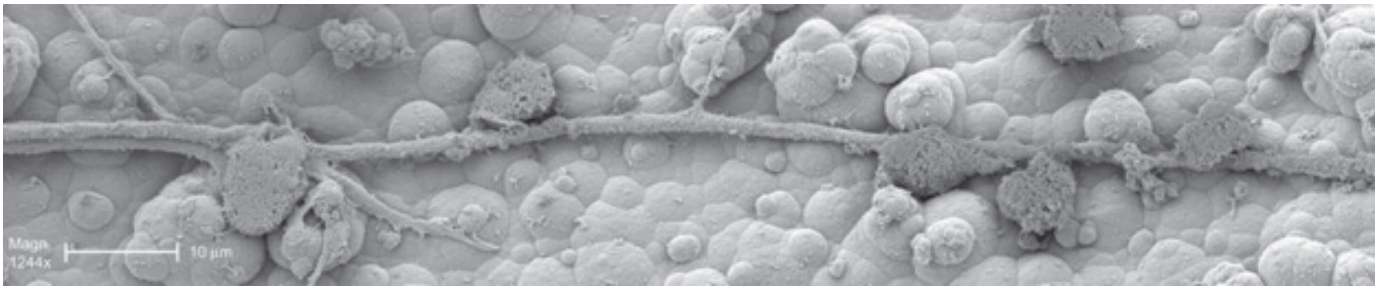


Figure 11: Low magnification view of neuronal explants showing extent of growth on polymer surfaces. The dopants used to grow the polypyrroles are (from top to bottom): CS, HA, DBSA, PTS, PSS, and PMAS.

Figure 10: High magnification of a hearing nerve growing on polypyrrole was achieved with a scanning electron microscope. It demonstrated that nerves make good contact with the nodular surface of polypyrrole.



Research highlights

Program 5: Ethics

The ACES Ethics program has two distinct roles: critical analysis of the social, ethical and political implications of novel electromaterials and development of a research training program for students and researchers that includes an introduction to values clarification, ethical debate and responsible science.

During 2006, considerable progress was made in the following three areas: student and early career researcher education; engagement with public policy-makers and developing research linkages. These are addressed below.

Education and Training

Researcher awareness of and engagement with the ethical, social and legal issues arising from emerging nanotechnologies was fostered through three events during 2006. These activities contribute directly to the educational aims of ACES.

- February 17th 2006 (during the Inaugural Symposium On Electromaterials Science) Prof Dodds organized a panel of ACES researchers– Maria Forsyth, Doug Macfarlane, Dermot Diamond, Maria Forsyth, Will Price, Leon Kane Maguire, David Officer– as well as the University of Wollongong's Commercial and Development Executive Officer, Troy Coyle, to participate in a hypothetical meeting of the (fictional) National Nanotechnology Strategy Council Subcommittee on Ethical, Social & Legal Aspects of Nanotechnology in Electromaterials Science (ESLANES). This role-play panel encouraged debate and discussion about what the ethical, legal and social issues of emerging nanotechnologies might be, from a range of stake-holder perspectives, with the aim of identifying key issues for further debate and possible policy development.

- August 23rd 2006 (Wollongong) Ethics and Regulation of Nanotechnology Workshop. This workshop (and the repeated workshop at Monash on 30 August 2006) aimed at early career researchers working in the nanotechnology area. The workshops were designed to stimulate researchers and students to consider their obligations as responsible scientists and how they would demonstrate to the Australian community the value of their research relative to a range of societal values. The workshops provided participants with an introduction to some emerging ethical and regulatory issues in nanoscience and nanotechnology. By asking participants to work in groups to develop some criteria for evaluation of nanotechnology research, they also provided an opportunity to develop skills in identifying and articulating responses to ethical and regulatory issues through case studies. Finally, they provided the opportunity to meet, talk with and hear the views of Australian researchers and practitioners in nanoethics and nanoregulation. Speakers at the Wollongong workshop were: Prof John Weckert (Charles Sturt University); Dr Peter Binks (NanoVic); Ms Diana Bowman (Monash). Approximately 35 attendees.

- August 30th 2006 (Monash) Ethics and Regulation of Nanotechnology Workshop. This workshop repeated the format and aims of the Wollongong Workshop. Speakers at the Monash workshop: Dr Robert Sparrow (Monash); Dr Peter Binks (NanoVic); Ms Diana Bowman (Monash). Approximately 18 attendees.

Engagement with public policy makers

In early 2006 the National Academies Forum won a tender to write a report on the ethical, social, legal and environmental aspects of the development of nanotechnologies in Australia for the National Nanotechnology Strategic Task Force (Commonwealth Department of Industry, Tourism and Resources). CI Dodds was invited to represent the Academy of the Humanities in Australia on the Steering Committee that met and made recommendations on the report as it was drafted. This activity has contributed to meeting the engagement milestones of ACES. The NAF report has now been published:

National Academies Forum (2006) Environmental, Social, Legal and Ethical Aspects of The Development of Nanotechnologies in Australia. A Report from the National Academies Forum for The National Nanotechnology Strategy Taskforce Department of Industry, Tourism and Resources. Available online at www.naf.org.au/nanotechnology.pdf

Research

During 2006 CI Dodds has initiated discussions with a number of researchers working on the ethical and regulatory aspects of nanotechnology. Among those involved in the discussions, potential for future research projects exist with the following:

"While there has been a lot of 'hype' about the effects of nanotechnology – at both ends of the spectrum – from the threat of apocalyptic night-mares and to promises of utopian panacea; the reality is that regulators, consumers and those who intend to manufacture products using nan-otechnologies simply don't yet know where these technologies may take us. It is prudent to be somewhat circumspect about the ethical impact of these technologies as their significance is largely in flux at this stage. Much more research in this area is needed."

Diana Bowman and Graeme Hodge (Law, Monash University) on the legal/regulatory aspects of nanotechnology; Rob Sparrow (Philosophy and Bioethics, Monash University) on the ethical implications of bionics and proprietary rights over biomedical electromaterials; Ian Kerr (Canada Research Chair in Ethics, Law & Technology, University of Ottawa) on the ethical and legal implications of wearable or implantable radio frequency identity devices; Jackie Leach Scully (Sociology, Newcastle University (UK)) on the scientific construction of ethical risk in nanoscience.

In addition, CI Dodds was invited to present a paper "Nanotechnology: Ethical and Social Issues" for a symposium on Nano-Manufacturing, Reliability, Standards, Safety and Ethical issues at ICONN (International Conference on Nanotechnology and Nanoscience, Brisbane 3-7 July). This paper and related work in progress contributes to a paper on the social-legal and ethical contexts of developments in electromaterials generally and more specifically bionics.

"Developments in nanoscience and applications of nanotechnology place high demands on social, ethical and regulatory commentators to see the relevant issues in all their contextual diversity– we need to become much more flexible in our analyses or risk irrelevance."

Education and training

The Education Committee's brief was to engage in education and training of both members of the Centre and the broader community through a range of activities. The Committee reports directly to the Executive Committee and is composed of Prof William Price (Chair – Chemistry, UoW), Prof Geoff Spinks (Materials Engineering, UoW), Prof Yi-Bing Cheng (Materials Engineering, Monash), Kaylene Atkinson (IPRI, UoW), Assoc Prof Peter Innis (IPRI, UoW) and Dr Toni Campbell (IPRI, UoW).

The goals in the first year of operation for the committee were to (i) establish a training program for staff and research students in the area of ethics and regulation in Nanotechnology; (ii) develop a series of workshops in the area of characterisation of nano-materials. In addition, it was proposed to start the community engagement program to increase the public's awareness of the usefulness of electromaterials and the work of the Centre.

In the first year, the Education Committee has been involved in the production of a CD which contains material on the fundamentals of what Electromaterials are and their applications and potential uses. This has been produced with a high school audience and general public in mind.

In addition, the Centre has participated in the exhibition "Science Exposed" at State Parliament House in Sydney, organised by the NSW Office of Science and Medical Research (OSMR), part of the NSW State Government. The exhibition attracted over 1700 students from 62 Schools, showcased the research of the Centre and the careers opportunities as well as the excitement and benefits of science to the community.

The Ethics and Regulation Workshops were two half-day events (at the University of Wollongong on 23rd August 2006, and at Monash University on 30th August 2006), supported through ACES and ARCNN for early career researchers and higher degree researcher candidates working in nanotechnology. Details are already provided under the highlights for Program 5 – Ethics. It is anticipated that the workshops will be run again next year with the prospect of attracting good numbers of external delegates.

The first in the series of characterisation workshops was held at the University of Wollongong in November 2006. The theme for the two day workshop was Synthesis and Characterisation of Carbon Nanotubes (CNT).

The workshop was restricted to internal members of the Centre and featured both theory and practical sessions in the manufacture and characterisation of CNT. Over 19 ACES members attended the workshop which was very well received. The feedback and lessons learnt form this workshop will be used to mount a revised format for the program which will be offered to external delegates in 2007. The format will also be used as a template for future events on characterisation techniques.

An educational CD has been produced which will soon be sent out to Schools. The CD covers different aspects of electromaterials science and its applications and is intended mainly for a senior science market. It is also intended to use the material gathered as the basis of other educational and promotional products for other markets such as general community outreach and industry, each tailored to the particular area.

In addition, as an initiative of the ACES Centre, a number of post-graduate students have been involved in outreach events visiting local schools in the Illawarra, NSW, explaining electromaterials science and the work of ACES to year 10 and 11 students. These have been very well received and more are planned for next year.

It is envisaged that more community outreach and educational events will be mounted by the Centre in the next few years, including liaising with the science centres at both Wollongong and Monash universities, to produce exhibits highlighting the benefits, science and applications of electromaterial science.

Graduate Training

Education and training have been mainly aimed at the PhD level. There are 27 PhD students, 2 undergraduates, and 3 interns (Appendix II). During 2006, 4 PhD students graduated; of whom 2 were from IPRI and 2 from Monash.

International Symposium February 2006

The CEO of the ARC, Prof Peter Hoj, officially opened the ARC centre of Excellence for Electromaterials Science on Thursday 16 February. The invited guests included Mr David Campbell (NSW Minister for Regional Development), and Professor Margaret Sheil (UoW Deputy Vice-Chancellor (Research) who represented the Vice-Chancellor.

Coinciding with the opening, ACES hosted a series of training workshops from 13 to 15 February 2006 followed by the first international symposium on electromaterials science at the University of Wollongong (held between 15 to 17 February 2006). The workshops covered topics on mechanical properties of polymers, modelling of polymer systems, and electrochemical methods. These topics provided: (i) an introduction to the

Prof Gordon Wallace addressing the gathering at the official opening.

mechanical behaviour of polymers and approaches to modelling materials properties and systems, with a particular focus on the nanoscale; and (ii) introduced/reinforced electrochemistry basics and advanced use of equipment to achieve characterisation of nanostructured electromaterials and optimisation of nanomaterial properties.

Presentations on the mechanical properties of polymers were made by Prof Hugh Brown (Steel Institute, UoW), Dr Tan Troung (DSTO), Prof Geoff Spinks (School of Mechanical, Materials & Mechatronic Engineering, UoW) and Dr Philip Whitten (IPRI, UoW). The second part moved onto mathematical and mechanical modelling of polymers and nanotubes and the software packages available to undertake these tasks. These presentations were given by Prof Jim Hill (Theoretical Mechanics, UoW), Dr Gursel Alici (School of Mechanical, Materials & Mechatronic Engineering, UoW), Dr Weihua Li (School of Mechanical, Materials & Mechatronic Engineering, UoW).

Techniques discussed for characterisation and optimisation were ESR/E-chem Raman spectroscopy, Fourier transform techniques and electrochemical mapping and impedance spectroscopy. Participants were also given the opportunity to hear about electrochemical surface engineering for production and characterisation of novel coatings, preparation and properties of nanoparticle composite coatings, photoelectrochemical cells and thermoelectrochemical cells.

These presentations were given by Prof Frank Walsh (School of Engineering Sciences, University of Southampton, UK), Prof Dennis Tallman (Corrosion/Coating Research Center, North Dakota State University, USA), Prof Alan Bond (Monash University), Prof Doug MacFarlane (Chemistry, Monash University), Assoc Prof Chee Too (IPRI, UoW), Assoc Prof Peter Innis (IPRI, UoW) and Dr Jun Chen (IPRI, UoW).

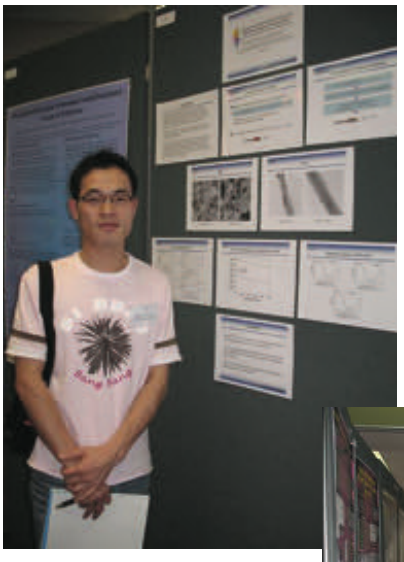
The workshops were attended by centre students and staff (approximately 23 UoW, 10 Monash and 5 international visiting students). After the workshop a briefing of centre members was held, with short updates given on new and current projects in the centre, as a way of introducing newer centre staff members. This was followed by a poster session where centre staff and students were joined by collaborators attending the symposium.

The Electromaterials Science Symposium, with a theme of the role and impact of nanostructure, attracted world class researchers from Australia, Canada, France, Germany, Ireland, Italy, Netherlands, New Zealand, United Kingdom, and the USA. The 17 invited speakers and their presentation titles are included in Appendix III.

In addition there were 56 poster presentations that covered topics that include the synthesis of conducting polymers, carbon nanotubes, other nanomaterials, nanofibres, and ionic liquids; and their applications in areas as diverse as solar cells, batteries, thermoelectrochemical cells, biofuel cells, actuators, sensors, and bionics.

Full Centre Meeting

A full Centre meeting was held on the 10th-11th of May 2006 at the Monash Science Centre in Melbourne. There were 52 attendees (Appendix IV) who came from the University of Wollongong, Bionic Ear Institute, St Vincent's Hospital (Melbourne), Monash University, Massey University and CSIRO. Oral and poster presentations were given and details are also included in Appendix IV.



Centre students were keen to present their research work and carry out fruitful discussions at the poster session that followed the centre workshops.

International profile

International Visitors

During 2006, ACES hosted a significant number of visitors (Appendix V) of whom 73 were from overseas; including those from China, Korea, Ireland, Japan, UK, USA, Canada, Denmark, Switzerland, France, New Zealand, Thailand, Netherlands, Italy, Sweden, India, Germany, and Saudi Arabia. ACES initiated or consolidated collaborations with these visitors. They included:

Prof Dermot Diamond

Dublin City University, Ireland.

Dermot's research interests include recognition, host-guest chemistry, ligand design and synthesis, electrochemical and optical chemical sensors and biosensors, lab-on-a-chip, sensor applications in environmental, clinical, food quality and process monitoring, development of fully autonomous sensing devices, wireless sensors and sensor networks. Particularly interested in developing the potential of analytical devices and sensors as information providers for wireless networked systems i.e. building a continuum between the digital and molecular worlds. Prof Gordon Wallace and Prof Dermot Diamond were successful in their application for an ARC Linkage International grant to consolidate their collaboration.

Prof Richard (Ric) Kaner

University of California Los Angeles, USA.

"It was a pleasure to return to Australia last year as a 2006 ARC Nanotechnology Network Distinguished Lecturer beginning with a presentation at the International Electromaterials Science Symposium sponsored by the new ARC Centre of Excellence for Electromaterials Science at the University of Wollongong. This gave me the opportunity to not only visit with lots of friends made during my Australian-American Fulbright sabbatical a year earlier, but to continue our excellent collaborations which have already resulted in a paper on polyaniline nanocomposites and a second on actuators made from flash welded polyaniline nanofibers. The ARC Centre of Excellence is an exciting place that makes possible interdisciplinary, international collaborations".

Ric's conjugated polymer research focuses on nanofibres of polyaniline and their use in sensors, actuators, molecular memory and flash welding. In 2005 he worked with Prof Gordon Wallace at the University of Wollongong on a Fulbright sabbatical fellowship.

Dr Mahendra Shirsat

The Dr Babasaheb Ambedkar Marathwada University, India.

"It was my pleasure to work as a Visiting Principal Fellow at the ARC Centre of Excellence for Electromaterials Science. It was a memorable experience for me to work with eminent scientists in the field of conducting polymers."

Dr Shirsat is a Reader in the Department of Physics. He spent two months with ACES conducting research in the development of carbon nanotube/conducting polymer composite electrodes for use as a glucose sensor.

Apart from visits from eminent scientists, ACES has also hosted visiting students such as:

Mark Steacy

Trinity College Dublin, Ireland.

Mark Steacy is a 4th year undergraduate student in the Physics and Chemistry of Advanced Materials degree at Trinity College Dublin, Ireland. He spent 3 months in ACES working towards his final year research project titled 'Studies on carbon nanotube poly-methoxy aniline sulfonate composites'. The research was carried out in both the solid-state and dispersions, in trying to understand the interactions of these two entities at the nanoscale. The composites were characterised by spectroscopic techniques, Raman and UV-vis Near IR spectroscopy, microscopy, scanning electron microscopy and mechanical data analysis, such as Thermal Gravimetric Analysis and Dynamic Mechanical Testing Apparatus.

"I thoroughly enjoyed my visit to ACES," says Mark. "It was a wonderful experience being with such a hard working, focused group of people working towards the same goals."

Overseas Visits

In addition to hosting a range of visitors, ACES personnel were invited to visit leading international laboratories such as in China, USA, Sweden, UK, Korea, Japan, Finland, and Switzerland (details in Appendix VI). A particular emphasis during 2006 has been to consolidate links in Asia.

Korean Visit June 2006

Professor Gordon Wallace and Dr Byung Chul Kim recently visited Korea to further consolidate important collaborative research linkages.

Hanyang University: Prof Geoff Spinks established links with Prof Seon Jeong Kim's group more than 2 years ago and recently completed an ARC International Linkage project that resulted in advances in formation of novel chitosan based composites and their use as artificial muscles. This work has resulted in a number of publications including a recent (January 2006) publication in *Nature Materials*. On behalf of the Intelligent Polymer Research Institute Prof Wallace signed a Memorandum of Understanding (MOU) covering collaborative research objectives during this visit to Korea (June 12th-15th).

Prof Seon Jeong Kim

Hanbat National University: IPRI has established collaborative research links in the area of new capacitor materials. Professor Ko who leads this group will spend a one year sabbatical at IPRI from August 2006. A jointly funded Research Fellowship has been established and Dr Byung Chul Kim has been appointed to this important position and is already making significant progress.

At Hanbat National University (Left to Right): Dr Byung Chul Kim (UoW), Professor Gordon Wallace (UoW), Professor Dong Ho Sul (President, Hanbat National University), Gi Wan Nam (Director, Centre for International Exchange), Professor Jang Myun Ko (Hanbat National University).

Sunchon National University: IPRI has established links with Professor Gyou-Jin Cho in the area of fabricating conducting polymer/carbon nanotube devices. Several students have visited our laboratories. A Centre – Centre MOU covering collaborative research was signed by Prof Wallace during his recent visit to Korea.

Consolidating links with China

2006 has seen ACES (IPRI) consolidate important research links in China.

Thanks to the efforts of Dr Jun Chen and Dr Dan Li, links with Hangzhou University of Technology (Electrosynthesis), Shanghai Jiao Tong University (New Electromaterials for Fuel cells) and Nanjing University of Science and Technology (Nanostructured Electromaterials) have been established.

Recently (December 2006) Professor Wallace visited China to present seminars on Nanostructured Electromaterials at Hangzhou University of Technology and Jiao Tong University. Professor Wallace also signed memoranda of understanding with both organisations.

During the visit to Jiao Tong University, Prof Wallace also visited the Shanghai Shen Li High-tech Co Ltd. The Shen Li company is a world leader in the manufacture of fuel cells and fuel cell engines. They along with other collaborators will produce 1,000 fuel cell buses in 2008. They expressed a strong interest in developing strategic research links with ACES.

India

In April 2006 Professor MacFarlane delivered an invited lecture at the 15th International Symposium on Non-oxide Glasses, on the topic of nanostructured luminescent materials which can be used as high resolution x-ray storage materials for medical imaging (such as the example below). ISNOG-15 was held at the Indian Institue of Technology Bangalore and attracted delegates widely from all over the world.

Sweden

Professor Graeme Clark was a Prominent Speaker at the 37th Nobel Mini-Symposium, Frontiers in Medicine. It was held at the Karolinska Institutet, Stockholm in May 2006. His oral presentation was on "Cochlear Implants, from bench to bedside, the multiple-channel Cochlear Implant – the sensory interface between the world of sound and human consciousness – the Melbourne experience".

The speakers are around the figure of Alfred Nobel. Prof Graeme Clark is 4th from the left.

USA

In July 2006 Professor Maria Forsyth was invited to attend the Gordon Conference on Aqueous Corrosion to be a Discussion Leader.

Professor Maria Forsyth was also invited to give two invited talks at the American Chemical Society National Meeting in San Francisco in September of 2006. In one case the talk was part of a Polymer Division Membrane Materials symposium and the other was a lecture on NMR techniques for diffusion measurements in materials as part of a Physical Chemistry Division symposium on Ionic Liquids.

Memoranda of Understanding

MOU's were signed with:

• **Hanyang University** (Korea) to undertake collaborative research with Prof Kim's group in the area of novel biocomposites.

• **Hanbat National University** (Korea) to undertake collaborative research with Prof Ko's group in the area of polymer capacitors.

• **Sunchon National University** (Korea) to undertake collaborative research with Prof Cho's group in the area of ink-jet printable conductors.

• **Shanghai Jiao Tong University** (China) to undertake collaborative research with Prof Ma's group in the area of fuel cells. This collaboration has been facilitated by the award of a UoW International Linkage grant.

Joint submission to the DEST Australia – India Strategic Research Fund

ACES has been integral in lobbying the Australian Department of Education, Science & Training to formalise its support for scientific co-operation between research groups here and in India. Nanotechnology was included on the list of priorities and a joint proposal was submitted in November 2006 for a focused workshop, with a view to developing formal collaborations through jointly funded research projects. The outcome of the application is expected in March 2007.

Successful linkage projects with academic partners

ACES was successful in securing Australian Research Council funding for international linkage activities with Dublin City University, Ireland. The title of the research project is: "Active polymer surfaces for control of fluid movement", with funding of $50,000 until 2008.

Invitations to address Conferences

Twenty-three invitations were accepted by ACES personnel to address conferences of which 18 were international. Details are given in Appendix (VII).

Outreach

2006 Innovation Week Public Lecture

Innovation Week unfolded at the University of Wollongong the week beginning Friday 5th May 2006, with the Innovation Week lecture delivered by the Executive Research Director of ACES, Professor Gordon Wallace.

The lecture addressed the widespread impact of nanotechnology in commercial products from sunscreens to new flat screen televisions. Nanotechnology also plays an important role in music (eg Elixir Guitar strings) and has historically played an important role in art and colour. This was celebrated as part of the lecture by a tune played with these guitar strings and some fancy footwork by an Irish Dancer wearing a colourful display dress (photo right).

The emerging job opportunities in Nanotechnology were discussed and the need for well trained nano-teachers highlighted.

Innovation Week Laboratory Tours

The ACES team opened up the laboratories to the public, on Tuesday 9th May 2006, offering guided Community Tours of the IPRI research facility which showcased their pioneering research into electromaterials science and nanotechnology. The tours allowed the community to find out more about smart plastics (polymers), plastics (polymers) that can conduct electricity, textiles that change colour, artificial muscles and research into a new generation of bionic ear.

The participants ranged from year 12 students, high school teachers, alumni fellow, occupational hygienists, interested retirees, radio host, community sector bankers, investment bankers and post graduate engineering students; and the researchers were appreciative of the captive and responsive audience.

IPRI research fellow, Carol Lynam, displays single wall carbon nanotubes in water to high-school students Ben Kresevic, James Mortimer (St Joseph's High School) and Mitchell Kejda (Albion Park High-School).

"Professorial Lecture" to the University of Wollongong

The fifth in the University of Wollongong's series of Professorial Lectures for 2006 examined artificial muscles, how they work and their many applications.

Professor Geoff Spinks from the Faculty of Engineering delivered the lecture on 26 July, 2006, and spoke about smart materials that respond by changing in size when stimulated. He also discussed how nanotechnology is improving their performance.

"Most commonly the stimulus is by an electrical voltage," he said. "These materials have applications in many areas including robotics, medical devices and micro-machines."

Professor Geoffrey Spinks talks about 'artificial muscles'.

Professor Spinks explained to his audience how his research has been dedicated to making artificial muscles work better and how he hopes to one day produce an artificial muscle that works as well as natural muscle.

"Since natural muscle works as a system of billions of co-ordinated nano-scale machines, we are looking to nano-scale materials to produce better artificial muscles," said Professor Spinks.

The 'Professorial Lecture Series' is an opportunity to hear about the research work and achievements

of academic staff members who have either been promoted to Professorial level or are recent appointments to the University.

Summer scholarships

Five undergraduate students won summer research scholarships to undertake projects within the Intelligent Polymer Research Institute. Three are students in the recently established B.NanoTec. Degree.

The Summer Scholarship holders worked on projects spanning the use of nanotechnology in thermoelectrochemical cells (harvesting energy from waste heat), to nanotube electrodes for biofuel cells – harvesting energy from biological systems. The results of these studies were presented at the Inaugural Symposium on Electromaterials Science hosted by UoW in February 2006.

Willo Grosse: Willo is a second year B.Nanotechnology student carrying out research that will lead to the development of new Carbon Nanotube based biofibres. These fibres are intended for use in the Bionics program of the new ARC Centre of Excellence.

Peter Sherrell: Peter is a B.Nanotechnology student. He is determining how important biomolecules interact with preformed Carbon Nanotube structures. The development of new bioelectrodes is envisaged.

Shannon Little: Shannon, before entering his Honours year in a BSc (Chem – advanced), worked on nano thermoelectrochemical cells with a view to developing new technologies that will harvest energy from waste heat.

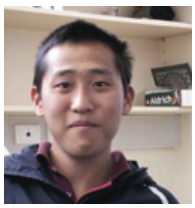
Luke Sweetman: Luke is a B.Nanotechnology student. He is developing new conducting polymer biocomposites that will be used in areas such as muscle and nerve cell regeneration.

Carl Tippler: Carl is a B.Env.Sci. student. He is investigating new biochemical cell technologies. The ultimate goal is to utilize naturally occurring biochemical reactions to generate energy in remote environmental situations. The same programs will also be able to develop implantable energy services.

The Monash University node of ACES also had summer scholars. Their details are given below:

Left: Peter Sherell, Shannon Little, Carl Tipper and Luke Sweetman busy in the laboratory. Right: Willo Grosse.

Lin Ji "Steven" - IL / metal interaction. Electrochemical analysis of IL film interaction with magnesium and magnesium alloys.

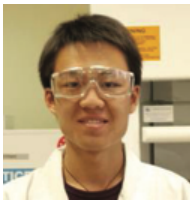


Xu Chao - Bio-batteries. Control of electrolyte/ magnesium reaction using aqueous electrolytes.

Kate Huynh - Plastic crystals. Methods for applying thin films and analysis of the films regarding conductivity and roughness.

Louise Vanderwerff - Surface immobilization of DNA-strains for direct self-assembly of DNA-tagged nanoparticles.

Julie-Anne Hill - Development of polymer electrolytes for solid-state dye-sensitized solar cells.



Dongshuan Fu - Development of graphite electrodes for monolithic dye-sensitized solar cells.

Visits to local schools

As part of the outreach program of the Centre, Professor Maria Forsyth and PhD student Nolene Byrne presented an "Electromaterials in Action" demonstration and talk to students at local Schools in Victoria.

Media coverage

During 2006, the activities of ACES personnel attracted media attention (Appendix VIII). Media reports were: 21 in print, 2 website, 8 radio, and 5 TV. For example, Prof Graeme Clark had media coverage by: Cosmos Magazine, Radio National, Channel 10, Wealth Creator Magazine, ABC Canberra, Bulletin, and Herald Sun.

Prizes and awards

Australian Academy of Science Travel Award

Dr Simon Moulton was successful in obtaining an Australian Academy of Science Scientific Visit Travel Award to Europe grant for FY2006-2007. The grant covers airfare and living expenses. He will work with Dr. Philippe Poulin at the Centre de Research Paul Pascal in Bordeaux. The work will involve studying the phase behaviour of SWNTs in biological solutions.

Best Student Presentation Award, ISOE

Scott McGovern (PhD student, IPRI) has been awarded the 2006 Best Student Presentation Award from the International Society for Optical Engineering (ISOE). Scott presented his paper based on his PhD work at the annual Smart Materials and Structures conference held in San Diego, USA in March 2005. The award was announced at the 2006 meeting. Scott's paper described his work on the development of a tiny moisture sensor capable of being inserted into tiny spaces, such as packaging, to detect damage to moisture-sensitive products. Scott's work is supervised by Profs Gordon Wallace and Geoff Spinks and is supported by Huntsman Chemical and the ARC.

Young Science Ambassadors Awards

PhD students Brianna Thompson and Jenny Halldorsson were awarded a grant from the Australian Research Council Nanotechnology Network to visit high school students in the local area, with the aim of inspiring students about nanotechnology and promoting science education. During the week of the 6th to the 10th of November, six schools in the Illawarra Region were visited as a part of the ARCNN Young Ambassador's program. The schools, in order of visits, were Shellharbour Anglican College, The Illawarra Senior College, The Illawarra Sports High, Warilla High School, Oak Flats High School and Keira Technology High School. The schools were chosen so that a cross section of the community was represented, with students from differing socio-economic backgrounds as well as varying age groups addressed. The groups of students included four Year 9 classes and four Year 12 classes, and as such, a variety of students at different levels were exposed to the presentation.

CRC Polymers Prize

The CRC for Polymers sponsors a prize for the best report in Australia based on project work in any field of polymer science or engineering. The prize includes a cash component of $1,500 and financial support to enable attendance at the 29th Australasian Polymer Symposium in February 2007. The competition is open to all students who have completed a research project as part of the requirement for a Bachelors or Honours degree in a relevant area of engineering, materials science or chemistry during the year 2006. Shannon Little was awarded this prize based on his BSc Honours thesis.

Other awards

- Dr Andrew Minett won a poster prize for his presentation at the International Conference on Nanoscience and Nanotechnology (ICONN2006), 3rd-7th July, Brisbane, Australia.
- Professor Maria Forsyth was awarded the Monash University Faculty of Engineering Research Excellence Award for 2006.

Taking nanotechnology into secondary schools.

Industry / end-user liaison

End-User Engagement

Our mission statement includes the aim to 'expand upon our reputation in electromaterials science and to see the Centre recognised as a world leader in the area'. We are implementing this aim through active engagement of end users with Centre-developed technologies. We define end users as industrial organisations that can use our technology for commercial return or scientific collaborators who may build on our findings or the general public at large, who may be interested in leading edge scientific research. Activities carried out in 2006 for each of these audiences are described below. Another critical component to implementing this part of our mission, is to strategically partner with new organisations, from either an industrial or academic background. New collaborations from academic partners are also included here.

Each of the outcomes presented below are underpinned by essential activities such as profile building, generation of promotional material and participation in key networks by the Centre's Business Development Officer and other Centre staff. Of particular value in 2006 were interactions with UWS Nanotechnology Network, Future Materials, the Ministry for Medical & Scientific Research, NSW Department of State & Regional Development and the Australian Research Council Nanotechnology Network.

Engaging Industry

Key achievements for 2006 include:

1. High level of industry participation at the annual symposium.
2. Launch of Centre website.
3. New industrial partners engaged: Cap-XX, Schefenacker Vision Systems.
4. End Users Committee established.
5. Facilitation of Centre visits from current and prospective industrial partners.
6. Key networking events.
7. Invited lectures to industrial audiences.

High level of industry participation at the annual symposium

Industry was also encouraged to attend the Inaugural Symposium on Electromaterials Science, that attracted 150 participants from both academic and industrial research organisations. The symposium outcomes included significant networking and new research opportunities across the Centre's activities.

Launch of Centre website

University-based websites are notoriously difficult to navigate, particularly for external users. To facilitate easier and better access to our research highlights, funding successes and awards, facilities and staff/student profiles, the Centre sought to establish its own website on an educational domain, requiring approval through the NSW Department of Education.

This was approved, with **www.electromaterials.edu.au** going live in April 2006. It is a valuable asset for co-ordinating Centre meetings amongst partner nodes, and also for communicating with end users. ACES is also in the process of developing an educational CD, which contains the introductory science to electromaterials such as conducting polymers, carbon nanotubes and ionic liquids, as well as background technical information on applications such as corrosion protection, bionics, sensors and actuators.

New industrial collaborators

Cap-XX: A key outcome from the Centre's symposium and attendance of the Business Development Officer at networking events throughout 2006 was the establishment of a joint project with Cap-XX, a leading supercapacitor manufacturer based in Sydney. The project will involve studies into new electromaterials for next generation supercapacitor devices.

Schefenacker Vision Systems Australia: In 2006 ACES researchers and collaborators in University of South Australia, were successful in obtaining Australian Research Council funding for a three year industrial linkage project with Schefenacker Vision Systems Australia. The development of flexible and conformal electro optical systems will strengthen Australia's position in the automotive industry establishing a value adding technology.

Other Collaborative Projects:
ACES continue to consolidate industrial linkages and other collaborative projects are given in Table 1 (see next page).

Establishment of End Users Committee

As part of its corporate governance strategy, ACES has constituted an industrial advisory board (known as the End Users Committee). The Centre Executive gave consideration as to the constitution and operation of the committee, and an informal information session was held in September 2006 to consult with current industrial partners of the Centre for their perspective. The composition of the End Users Committee is: Peter Riley (BlueScope Steel), Jim Patrick (Cochlear), Phil Aitchison (Cap-XX), Tan Truong (DSTO), Ray Shaw (Rio Tinto) and James Nicholson (Schefenacker). The first formal meeting was held in January 2007.

Table 1: Other ACES collaborations

	Project	Duration	Source of Funds
CRC Cochlear Implants and Cochlear Pty Ltd	Conducting Polymer Actuators and Sensors for Cochlear Implants	2003-2006	CRC Cochlear Implants
CRC Functional Surfaces	Conducting Polymer Sensors for Packaging	2003-2006	CRC SmartPrint
CRC Int. Manufacturing	Smart Mirrors	2004-2006	CRC IMST
Rio Tinto	Electrowinning using Ionic Liquids	2004-2007	Rio Tinto
DSTO	Artificial Muscles	2003-2007	DSTO
CRC Polymers and CSIRO (Holmes)	Polymer Photovoltaics	2006-2008	CRC Polymers
Boston Scientific (USA)	New Platforms for Cell Culturing	2004-2006	Boston Scientific
DLG Battery (Shanghai) Ltd	Miniature lithium ion battery for implantable medical device applications	2007-2009	ARC LP
Pacific Lithium New Zealand Ltd. (New Zealand)Sopo Battery Energy Co. Ltd (China)	Large-scale rechargeable battery for power storage and electric vehicle applications	2004-2006	ARC LP
Guangzhou Delong Energy Tech Ltd (China)	Exploration of new catalyst materials for hydrogen/air fed exchange membrane fuel cells	2007-2009	ARC LP
Guangzhou Delong Energy Tech Ltd (China)	Lithium/sulphur rechargeable battery for power application	2004-2006	ARC LP

Facilitation of Centre visits from current and prospective industrial partners

During 2006, ACES has conducted laboratory tours for visitors from industry on 39 occasions - with representatives from 15 different companies based primarily in Australia, the US and Japan. Examples of some of these representatives include: BlueScope Steel, Schefenacker Vision Systems, Ciba Geigy, Boston Scientific, ThinkCentric and Cap-XX. These visits are valuable for industry as technology awareness and 'horizon watching' opportunities. In addition to laboratory visits, there has been considerable phone and email contact with potential industry partners to identify research synergies, including EZI Technologies, Water Innovations and BASF (via Invest Australia).

Key networking events

The position of Business Development Officer has facilitated greater participation in industrial networks, such as TTNA and the UWS Nanotechnology Network. Key meetings have developed from introductions made through these informal networking events. Networking events hosted by the NSW Department of State and Regional Development have also been invaluable in increasing the exposure of the Centre. These activities, in addition to personal networking activities undertaken by Centre staff, are important to securing new, as well as maintaining existing industry links.

• **ACES at NCRIS briefings** – The Business Development Officer and Deputy Director of IPRI attended briefings and meetings hosted by the NSW Department of State and Regional Development to ensure a role for ACES in the National Collaborative Research Infrastructure Strategy (NCRIS). We were subsequently successful in securing the Fabrication node for Materials, sharing $2million with the University of Newcastle.

• **ATS Health Technology Expo, Sydney** – This event, hosted by the Australian Technology Showcase (ATS) in April 2006 provided an opportunity to showcase ACES research, along with the latest and most advanced NSW health technologies, including biopharmaceuticals, diagnostics, e-health solutions and medical devices to companies, investors, other researchers and interested parties. The aim for ACES was to identify synergies and collaboration opportunities with other public and private sector organisations and

to get an update on the latest research activities underway in NSW in the health and medical field.

Invited lectures to industrial audiences

ACES has participated in a number of events during 2006 that attract large audiences or have an international focus, irrespective of whether the audience is largely scientific or business oriented. This is a key mechanism for engaging end users and some of these events are highlighted below:

• **44th Australia-Japan Joint Business Conference, Sydney** – Executive Research Director of the ARC Centre of Excellence for Electromaterials, Prof Gordon Wallace, recently delivered a lecture to the 44th Australian-Japan Joint Business Conference, held in Sydney 17th October 2006. Prof Wallace introduced the Centre's Bionic Research program to a 300 strong delegation of Japanese and Australian business representatives.

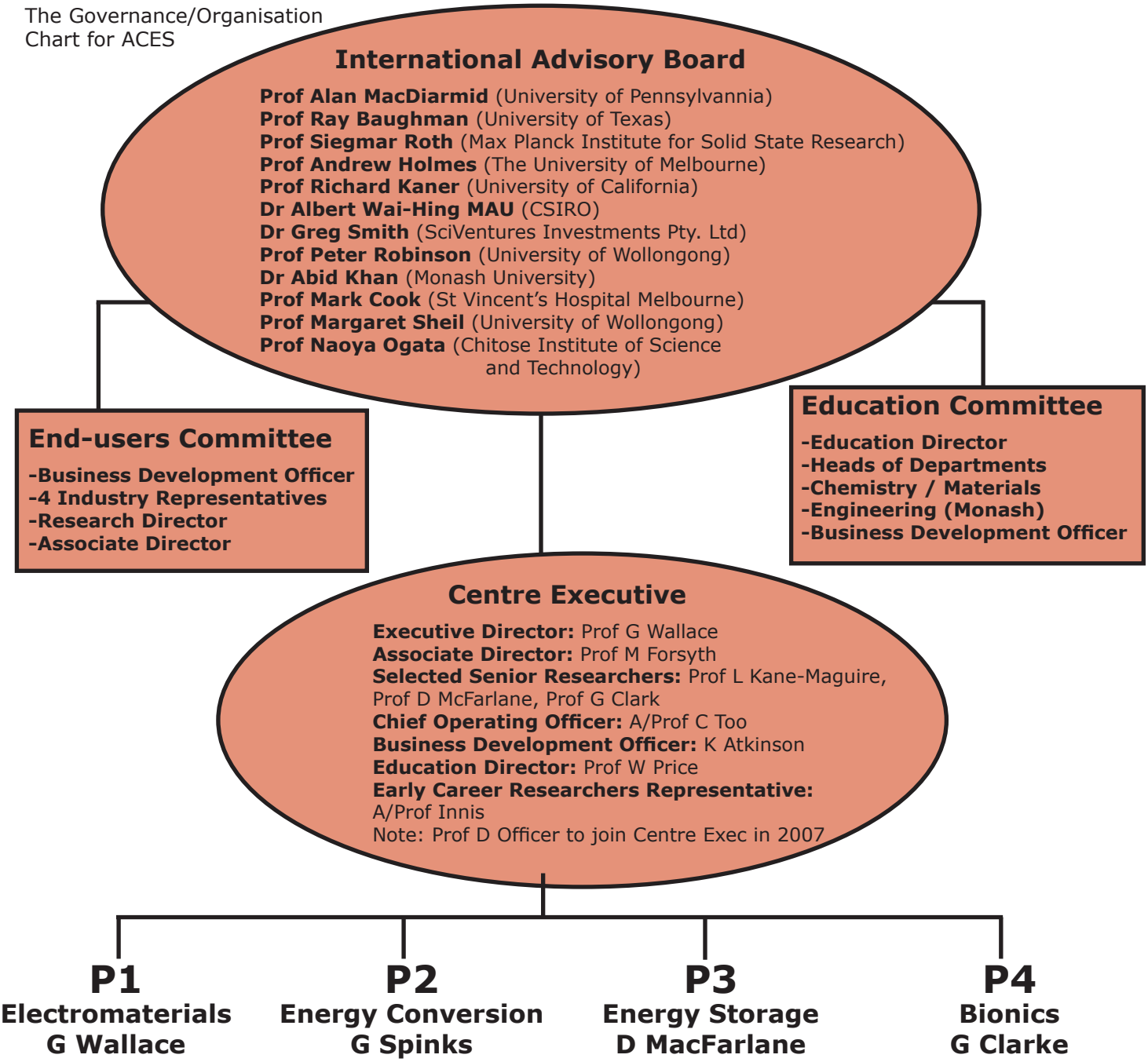
• **World Congress on Medical Physics and Biomedical Engineering, Seoul, Korea** - Prof Wallace delivered a plenary lecture at this event in September 2006 where 2,500 scientists, engineers and medical practitioners from 69 countries gathered to present and discuss the latest developments in areas such as new health monitoring technologies, home health care, biosensors, bioinformatics and bionics.

• **Cutting edge research showcased at student conference, Wollongong** - Two ACES students, Jenny Halldorsson and Javad Foroughi presented their research work as part of the University of Wollongong Higher Degree Research Student Conference in September 2006, and the plenary session was given by Prof Wallace. Attended by students, industry partners and academic and general staff, the conference showcased the diverse range of projects being undertaken by University of Wollongong research students based on five themes - promoting and maintaining good health, frontier technologies and scientific discovery, cultivating creativity and innovation, understanding societies and culture and understanding our environment.

Prof Wallace at the Seoul World Congress.

Management and staff

The Governance/Organisation Chart for ACES



During 2006, an International Advisory Board meeting was held on 15th February, a full centre meeting was convened 10-11 May at the Monash Science Centre, and 6 Executive Committee meetings were held on 15th February, 15th March, 12th April, 30th May, 11th August and 17th November 2006.

The Education Committee was established and consists of: William Price, Geoff Spinks, Kaylene Atkinson, Peter Innis, Toni Campbell from the University of Wollongong, and Yibing Cheng from Monash University.

The End-Users Committee was also established and consists of: Peter Riley (BlueScope Steel), Jim Patrick (Cochlear), Phil Aitchison (Cap-XX), Tan Truong (DSTO), Ray Shaw (Rio Tinto) and James Nicholson (Schefenacker).

Staff and students

The Centre is led by the Executive Director, Professor Gordon Wallace of the IPRI who is recognised as a world leader in electrode materials. He is assisted by Professor Maria Forsyth (Monash University) as Associate Director. The day to day management/administrative activities of the Centre are overseen by Associate Professor Chee Too as Chief Operating Officer.

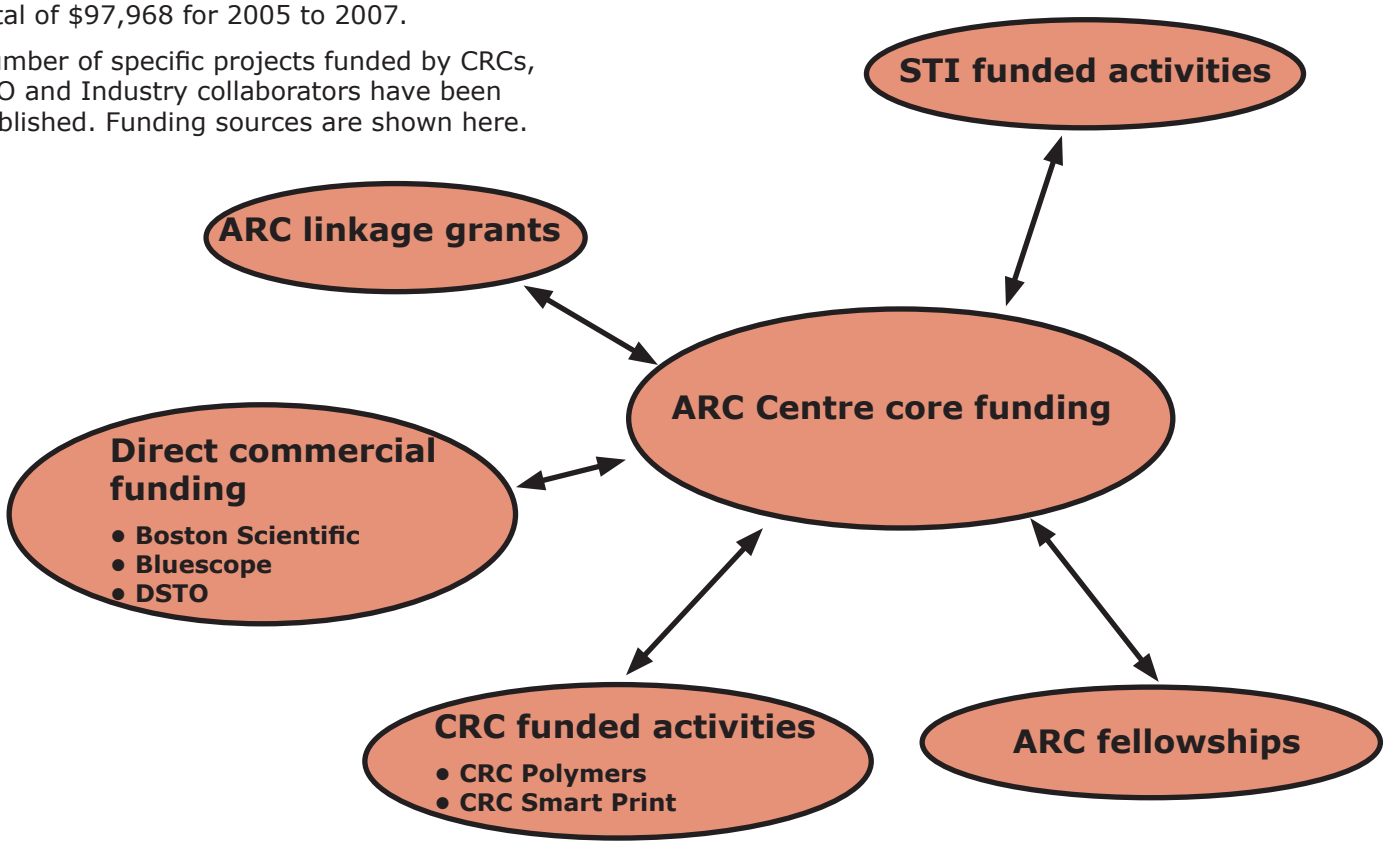
Centre Students and Staff details are provided in Appendix II and Appendix IX respectively. The Centre comprises of 27 PhD, 2 undergraduate and 3 intern students, 17 Chief Investigators, 2 Partner Investigators, 35 Associate Investigators, 19 Research Fellows, 1 Senior Research fellow, 4 ARC Fellows and 1 QEII Fellow.

Income and expenditure

Income from other sources

The NSW State Government is providing a total of $97,968 for 2005 to 2007.

A number of specific projects funded by CRCs, DSTO and Industry collaborators have been established. Funding sources are shown here.



Income and expenditure for 2006

A certified Centre Outputs and Detailed Income & Expenditure Report (CODIE) will be submitted to the ARC separately to the Annual Report.

Anticipated income and expenditure for 2007

The disbursements of Centre income for 2007 was ratified at a Centre Executive Committee meeting on 8th February 2007.

Performance indicators

Publications

The target for 2006 was 30 refereed publications of which at least 15 would have an impact factor greater than 2. We have greatly exceeded these targets with a final result of 61 refereed publications of which 33 have an impact factor greater than 2. The publications list is given at Appendix X.

Other indicators

The Key Result Areas and Performance Measures Schedule for the Centre is given at Appendix XI. In general the performance of the Centre has exceeded our targets. In addition to publications ACES lodged 11 patents, accepted 18 invitations to international conferences, made 22 visits to leading international laboratories, was featured in 36 media reports, received 73 international visitors, and recruited 7 new organisations to collaborate with the Centre.

Report on Activity Plan for 2006

A complete milestones report with original and refined milestones is given in Appendix I.

Year 1 milestones are highlighted below. For activities related to milestones for other years, refer to Appendix I.

P1. Electromaterials

• Establish wet-spinning fibre drawing facilities (end Year 1).

We have successfully identified the key requirements for efficient wet-spinning of organic conducting fibres, based on interesting conducting polymers and/or carbon nanotubes. The "counter current" wet spinning coagulation system originally developed at UT Dallas was refined and established in our laboratories. Conducting Polymer Carbon nanotube fibres with the highest combination of conductivity and mechanical strength reported to date have been produced.

We have also produced carbon nanotube biomolecule composite fibres with a combination of the highest conductivity and mechanical properties reported to date. With the optimised spinning parameters, we have effectively spun various fibre types and compositions of highly electrically conducting and biologically friendly fibres including combinations from inherently conducting polymer (i.e., polyaniline and polypyrrole) and biopolymers (hyaluronic acid, chitosan, DNA, heparin, etc.) with carbon nanotubes.We have identified and tested a fully automated lab-scale spinning-drawing machine that is currently being manufactured in Japan that will be acquired early 2007.

• Prepare functionalised aligned CNTs for P2 and P3 (end Year 1 then ongoing).

Refined milestone: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.

In 2006, progress has been made towards this milestone on several convergent research fronts. A key piece of equipment has come online during 2006 allowing more control during and reproducibility of the Chemical Vapour Deposition (CVD). A fully automated thermal CVD integrated system was purchased from Atomate (Santa Barbara, USA) and installed in February 2006. The procedures used previously for preparing aligned nanotube forests have been optimised and successfully transferred to the new equipment. Samples of controlled length and controlled tube density have been produced (Figure 12).

The simplest route to "functionalising" aligned carbon nanotubes has been adopted during

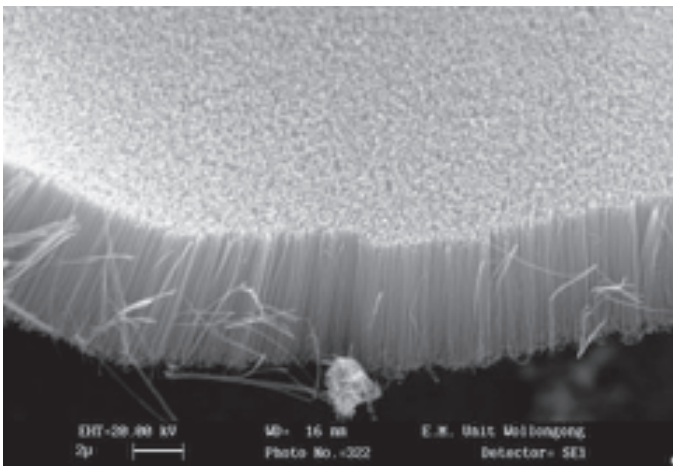


Figure 12: A forest of aligned carbon nanotubes.

2006. This involves imbibing functional molecules into the interstitial volume between the tubes. To date bio materials such as poly(styrene-beta-isobutylene-beta-styrene) (SIBS) and conducting polymers such as PEDOT have been integrated. This approach will be used to provide the functionalised carbon nanotube arrays, required for P2, P3 and P4 and specified above during 2007. Attempts to covalently functionalise CNTs (see Program Milestone 1) have highlighted the significant challenges to be overcome here.

P2. Energy conversion ·

Establish basic mechanisms of gel adhesion to electrodes (end Year 1).

The work related to this milestone has been mainly concerned with developing an understanding of the adhesion of ionic gels to charged and uncharged substrates. Both anionic and cationic gels have been synthesized and their adhesion to each other and to oppositely charged substrates has been measured. The adhesion is found to be highly dependent on the pH and the ionic strength of the environment, as it is caused by 'counter-ion evaporation', that is the free energy, mainly entropy, change when a polymeric counter-ion is exchanged for a small molecule counter-ion, releasing the small molecule counter-ion into the solution. At neutral pH and at low ionic strength the adhesion is strong enough to cause cohesive failure within the (untoughened) gels.

As gels with high adhesion need also to be tough (as do gels that are useful as actuators) it has proved essential to gain an understanding of the techniques for making tough gels. To this end a collaboration has been initiated with Professor J. P. Gong of Hokkaido University whose group has developed tough, double network gels. A theory of the mechanism by which the existence of the two networks toughens of these double network gels has been developed and submitted for publication. Some of its predictions are currently being tested.

P4. Bionics

• An understanding of the interfacial chemistries required for efficient cell adhesion and cell proliferation (end Year 1).

Understanding the interfacial chemistries for efficient cell adhesion and proliferation to electroactive polymers has application for improved cochlear implant hearing prostheses, and the restoration of spinal cord function. The research in the Bionics program has demonstrated the electrical stimulus parameters for the uptake and release of the protein NT-3 for nerve preservation and growth. The electrical parameters that are essential for the safe transfer of electrical energy for neural stimulation are also effective for the release of NT-3.

In addition, the research is showing that the dopants used to develop the polymer have a significant effect on NT-3 uptake and release. The adhesion of neurites to the polymer is important for cell growth, and in particular the extension of the neurite processes (axons and dendrites). It has been shown that the adhesion varies depending on the dopant, as well as a film containing adhesion molecules.

The surface topography of the polymer may influence neuronal extension and is being controlled for in further studies. The interaction between neurite and polymer is being further investigated using Fourier Transform Infra-red Spectroscopy. The interfacial chemistry is being modelled, and in particular to determine the effect of hydrophobicity on the uptake and release of NT-3. Research is in progress to develop invitro tank studies to specifically investigate the effect of stimulus parameters such as current strength and density on neural growth. In addition, the research is in progress to produce configurations of carbon nanotubes to be used with polypyrrole and nerve growth factors as preliminary research for Milestone 49. This involves biocompatibility, invitro and invivo stimulus and release studies and the application to experimental animal models.

Education milestones

• Establishment of ethics program and first cohort of staff and students trained (end Year 1).

See Education and Training Report.

• Development of characterisation short courses and workshops (end Year 1).

See Education and Training Report.

New Research Initiatives

• Self-powered functional devices

The concept of self-powered functional devices has been developed and patented. This relates to autonomous sensing systems but also to medical implants. In the latter, power can be generated to induce electrical stimulation of cells or to induce controlled release from a polymer.

• Ink-jet printable nanodispersions for chemical sensing

In collaboration with Dublin City University these sensors are easily produced and have been shown to be highly effective sensors.

Equipment and Infrastructure

Equipment was acquired via organisational as well as collaborative support during 2006.

Planning for the construction of a new building to host ACES at UoW's Innovation Campus has been completed.

Governance

The IAB met on February 15th 2006 (minutes in Appendix XII).

Executive meetings were held on 15th February, 15th March, 12th April, 30th May, 11th August and 17th November 2006 (minutes available).

Education committee meetings were held on 6th April, 1st August and 5th December 2006 (minutes available).

An End Users committee has been established.

Report on Activity Plan for 2006

Intellectual property

The management of the Centre's intellectual property is documented in the ARC Collaboration Agreement. This policy provides a framework to all Centre researchers, and establishes the ownership rights and responsibilities of Centre researchers with respect to intellectual property protection and subsequent commercialisation. An IP register of Centre IP and background IP is maintained and circulated on a yearly basis. The Centre relies on the expertise of the lead nodes commercialisation staff to advise on IP issues, patent protection and other strategies. All IP transactions are handled by the Centre's Executive Research Director. The Centre has carried out training for staff/students in IP management in 2006.

Key patent applications lodged in 2006 cover research advances in biofibres, textile batteries, actuating sensors and novel nanoelectrodes. Full details of the 2006 patent applications are included in the Centre's IP Register given at Appendix XIII.

Education and Outreach

Please refer to sections on "Education and Training" and "Outreach Activities".

Activity Plan for 2007

Our strategic objectives for 2007 fall under the core activities of the Centre.

Research Programs

The core activities for 2007 will be focussed mainly on the Year 2 milestones given below. Milestones for other years (see Appendix I) will also be addressed where applicable.

P1. Electromaterials

P1-1 Synthesis and Processing

Synthesis of nano-organic materials

Milestone 5: Supply of new materials to P2-P4 (ongoing).

Synthesis of nano-inorganic materials

Milestone 6: Prepare thin-film cathodes and anodes for P3 (end Year 2).

Milestone 7: Development of efficient ZnS nanoparticle synthesis (end Year 2).

Processing

Milestone 12: Prepare functionalised aligned CNTs for P2 and P3 (end Year 1 then ongoing).

Refined milestone: 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 13: Establish sol-gel methods for self assembly (end Year 2).

The research for this milestone is to be incorporated into Milestone 9.

Milestone 14: Supply of fabricated structures to P2-P4 (end Year 2 then ongoing).

Functional electrolytes

Milestone 15: Develop and characterise enhanced performance electrolytes including plastic and solid gel electrolytes (end Year 2).

Milestone 19: Supply/refinement of electrolytes for P2-P4 (end Year 2 then ongoing).

For P2 requirements, see milestones 27 and 32.

For P3 requirements, see milestone 36.

P4 requirements – biocompatible electrolytes for bio batteries.

P1-2 Characterisation

Milestone 20: Establishment of co-ordinated characterisation users' network (end Year 2).

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).

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 (ongoing).

P2. Energy conversion

P2-2 Electromechanical Actuators

Milestone 30: Develop phenomenological models of ICP and gel actuation under low voltage electrochemical stimulus, taking into account the influence of ion movements, osmotic effects, chain conformation changes and changing mechanical properties (end Year 2).

P4. Bionics

P4-1 Nerve cell communications

P4-2 Bio-stability and biocompatibility

Milestone 48: An understanding of how energy transfer processes (electrical, optical stimulation) influence these interfacial chemistries (end Year 2).

P5. Ethics

P5-1 Biosystems, Electromaterials and Commodification of Human Health

Milestone 51: An understanding of the social-legal and ethical context of developments in bionics (end Year 2).

Research “New” Initiatives

Equipment and Infrastructure

Major equipment (including new NMR facilities) will require the lodging of a LIEF proposal in 2007.

Governance

The End Users Committee will have its first year of operation.

Intellectual Property

Further refine the strategic IP position to be the focus of the Centre. Continue to lodge patent protection in that area. Work with host organisations to develop the most appropriate commercialisation strategy.

Education and Outreach

Activities with Science Centres attached to host organisations will be further refined and developed.

Appendix I: Milestones Report

ACES Milestone Report

The following milestones relate to the core research programs of the ACES. Materials produced in the course of these activities are also utilised in "other" centre programs such as inkjet printing, catalysis, sensors etc.

P1. Electromaterials

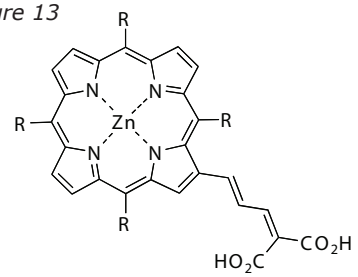
P1-1 Synthesis and Processing

Synthesis of nano-organic materials

Milestone 1: Prepare porphyrins, oligothiophenes, ferrocenes and fullerenes for attachment to ICPs, CNTs and nano-inorganic materials for P2 and P3 (end Year 3).

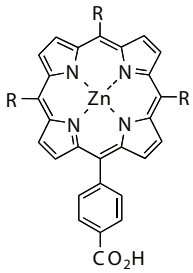
A wide variety of porphyrin dyes have been prepared for attachment to titanium dioxide. Of particular note, are the malonic acid porphyrins and the new benzoic acid porphyrins (Fig. 13).

Figure 13



R = Ph, tolyl, xylyl, t-butyl, 3,5-dit-butyl, mesityl, and arylpolyether

Malonic acid porphyrin derivatives

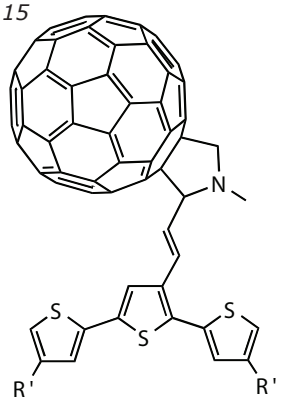


R = Ph, tolyl, xylyl, mesityl

Benzoic acid porphyrin derivatives

In particular, two new terthiophene fullerene derivatives have been prepared (Fig. 15).

Figure 15



R = H or $OC_{10}H_{21}$

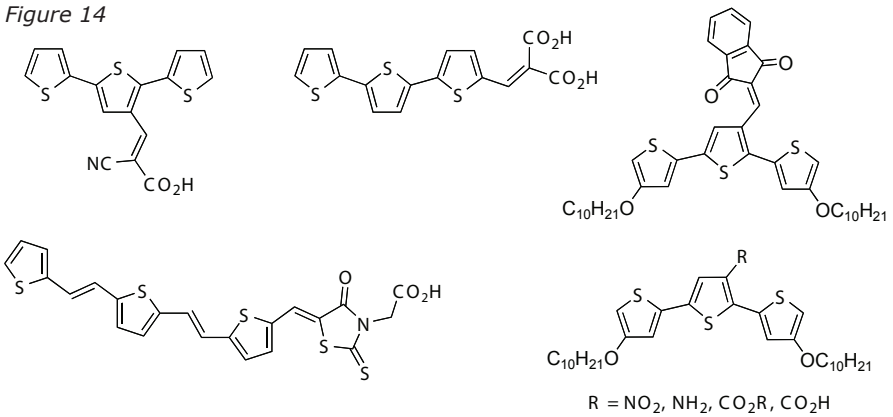
Terthiophene fullerene derivatives

Milestone 2: Prepare cell growth promoters, peptides and polyelectrolytes for P4 (end Year 3).

This milestone has been refined and will target the attachment of the nerve growth promoter NT3 to a polyelectrolyte backbone and subsquent incorporation of this into polypyrrole.

The preparation of functionalised terthiophenes and oligothiophenes for attachment to titanium dioxide and the preparation of polymers has continued. Some examples of new materials are shown below (Fig. 14).

Figure 14



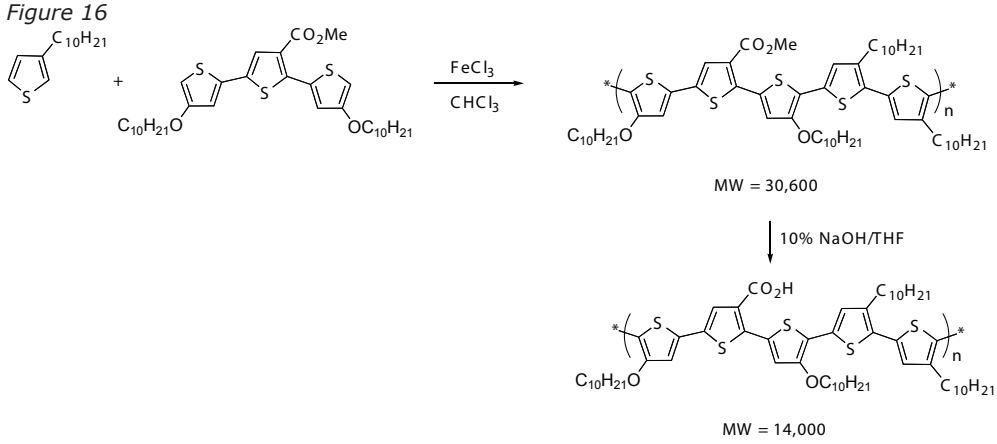
R = NO_2, NH_2, CO_2R, CO_2H

Examples of functionalised thiophenes and oligothiophenes

Milestone 3: Prepare functionalised ICPs and CNTs for P2 and P3 (end Year 3).

The focus in the polymer area in 2006 has been on the preparation of processable functionalised poly(terthiophene)s. This requires the formation of polymers of masses greater than 20,000 kD. This can be achieved for the methyl ester copolymer. However, on hydrolysis to the carboxylic acid, the highest molecular weight soluble polymer fraction that can be isolated is 14,000 (Fig. 16).

Figure 16



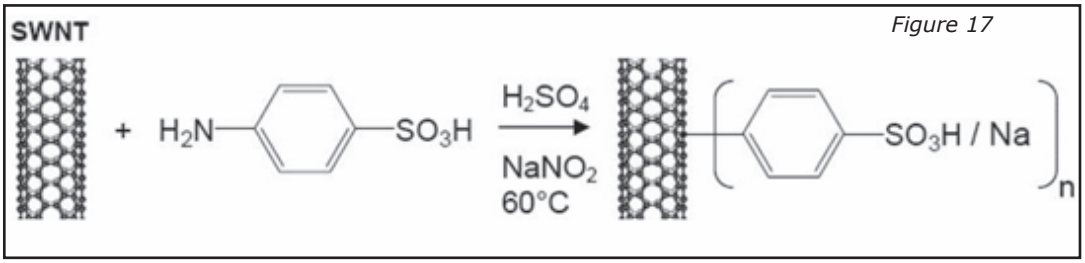
Formation of soluble acid-functionalised polythiophene copolymer

Solution-Surface Electropolymerization: A Route to Morphologically Novel Poly(pyrrole) Using an Ionic Liquid. J.M. Pringle, M. Forsyth, G.G. Wallace, D.R. MacFarlane, *Macromolecules* 2006, 39, 7193-7195.

Conducting polymer nanoparticles synthesized in an ionic liquid by chemical polymerisation. J.M. Pringle, O. Ngamna, J. Chen, G.G. Wallace, M. Forsyth, D.R. MacFarlane, *Synthetic Metals* 2006, 156, 979-983

Single walled nanotubes (SWNT) have been covalently functionalised to give the sulphonate substituted SWNTs as illustrated below (Fig. 17). This fascinating "polyelectrolyte" has been shown to dope polypyrrole during polymerisation and to act as a molecular carrier to facilitate protein incorporation.

Figure 17



Milestone 4: Elucidate biomolecule – nanosized bioconjugate interactions (end Year 3).

The synthesis protocols for preparation of the sulfonated polyaniline (PMAS) have been optioned to yield a high purity product with a low molecular weight distribution. This material is highly water soluble and conductive. Adopting Kaner's protocols for synthesis of nanofibres we have produced polyaniline nano-materials containing PMAS as dopant.

Nanostructured conducting polymer materials have been prepared by Dr Jenny Pringle which also have potential use in battery and capacitor applications. Figure 18 shows nano particles of silver embedded in a conducting polymer matrix. Capacity and electrochemical properties of the materials are being investigated.

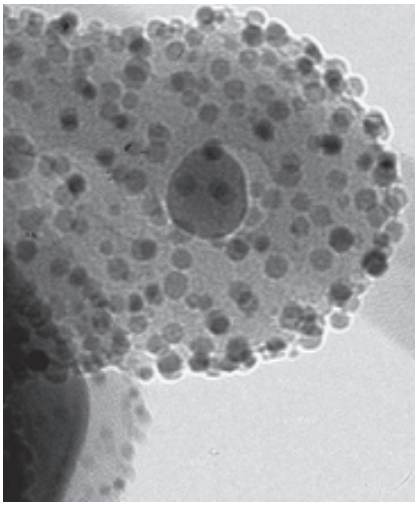


Figure 18: Nano particles of silver embedded in a conducting polymer matrix.

New Metal Complex-Biomolecule Hybrids as Redox Sensor

An X-ray structure of a zinc complex bearing a ferrocenyl arm (**Receptor 1**) complexed with the DNA base thymine has been obtained (Fig. 19).

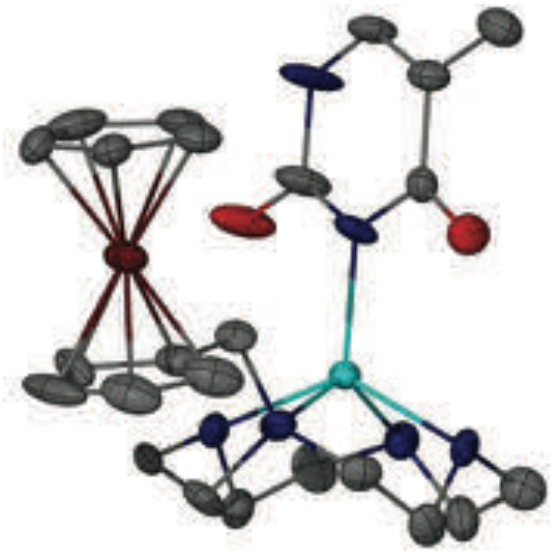


*Figure 19: ORTEP plot of **Receptor 1** complexed with thymine (hydrogen atoms and perchlorate anion omitted for clarity).*

Appendix I: Milestones Report

Electrochemical studies have been completed, however signals arising were found to be insufficient to be considered useful in the biosensor area. With this in mind a new copper complex (**Receptor 2**) was synthesised (Fig. 20) that a greater electrochemical shift will be encountered since the CuII/I redox couple is involved in the complexation of the DNA base.

It was also found that the copper centre in **Receptor 2** binds strongly to nitrate anion. Electrochemical and UV-vis studies are currently being carried out to determine whether **Receptor 2** could act as anion sensor.

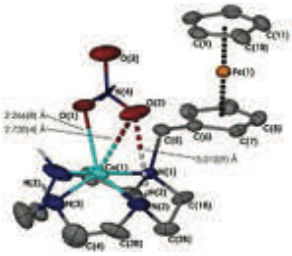


*Figure 20: ORTEP plot of the **Receptor 2** (hydrogen atoms and perchlorate anion omitted for clarity).*

A convenient synthetic procedure has been used to produce a new ferrocenyl uracil Peptide Nucleic Acid (PNA) **Receptor 3**. Electrochemical measurements showed that 3 exhibits a single and reversible one-electron wave with a diffusion coefficient that is slightly larger than observed for similar ferrocenyl PNA monomers.

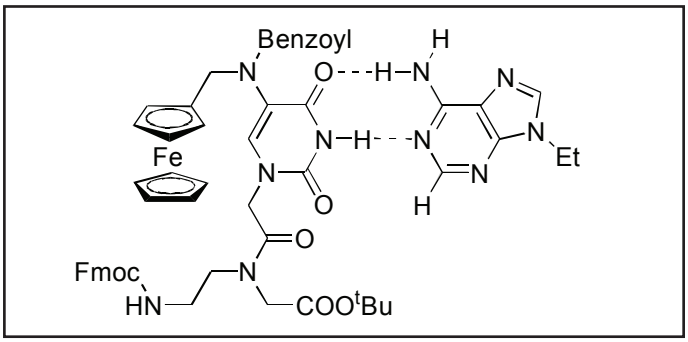


Figure 21: Watson-Crick pairing between 3 and EA.

Work currently in progress is incorporating the **Receptor 3** into PNA oligomers for use as redox sensors for specific DNA/RNA sequences.

Milestone 5: Supply of new materials to P2-P4 (ongoing).

As indicated above, new materials continue to be developed to meet the needs of the P2-P4 programs.

P2 - Energy conversion: A range of functionalised thiophenes have been produced for use in solar cells based on TiO_2 or conducting polymers.

P3 - Energy Storage: In addition, functionalised terthiophenes (Fig. 22) have been produced for the development of all-polymer batteries during 2006 (P3-3).

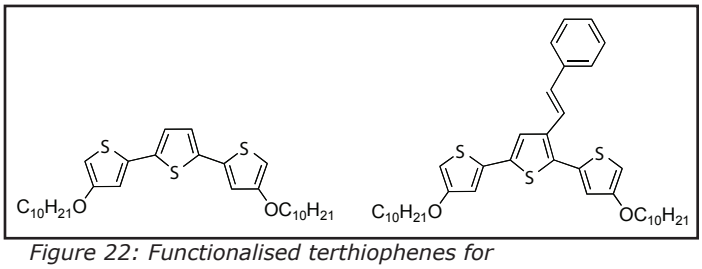


Figure 22: Functionalised terthiophenes for organic battery development in P3-3

P4 - Bionics: The purified sulfonated polyaniline material (PMAS) has been supplied for use as a dopant in polypyrrole for bionic applications. PMAS was also supplied to "other programs" for dying textiles and inkjet printing.

Synthesis of nano-inorganic materials

Milestone 6: Prepare thin-film cathodes and anodes for P3 (end Year 2).

Amorphous Si thin films have been deposited directly on to stainless steel substrates that act as current collectors using the pulsed laser deposition (PLD) technique. The "Si thin film" electrodes prepared by PLD showed good cycle life without abrupt capacity fade over 70 cycles.

Mesoporous gold sponges were prepared by chemical removal of Al from thin films of an $AuCl_2$ precursor that had been deposited onto Cu sheet.

The multilayer mesoporous Au film showed superior characteristics compared to an ordinary Au film, with a higher specific charge passed. Capacity of all electrodes tested was of the order of 500 mA.h.g^{-1} during the initial discharge cycle. However, a steep fade occurred during subsequent cycles. The capacity of the multilayer, mesoporous gold settled at about 80 mA.h.g^{-1} after 30 cycles, while that of the ordinary Au film fell to about 10 mA.h.g^{-1}.

Milestone 7: Development of efficient ZnS nanoparticle synthesis (end Year 2).

The PhD student to work on ZnS commenced July 2006. However, during 2006 CdSe quantum dots, nanocrystalline semiconductors that have potential applications across many fields ranging from electronics (LEDs, photovoltaics) to the life sciences (fluorescent tags for biological molecules) has been addressed. To date, synthesis of semiconductor quantum dots such as CdSe has been reported in volatile organic solvents at high temperatures. This is a costly process and could be difficult to scale up. The use of a new class of solvent, namely ionic liquids, for the synthesis of CdSe quantum dots has been investigated during 2006.

Ionic liquids offer a number of significant advantages over volatile organic solvents including low vapour pressure, low flammability and exceptional chemical and thermal stability. A series of phosphonium ionic liquids with different anions were examined in this work and it was found that, with non co-ordinating anions, CdSe quantum dots with identical spectroscopic properties to those

produced in organic solvents were readily prepared.

Milestone 8: Prepare porphyrin-functionalised Au or ITO surfaces for photoelectrodes in P2 (end Year 3).

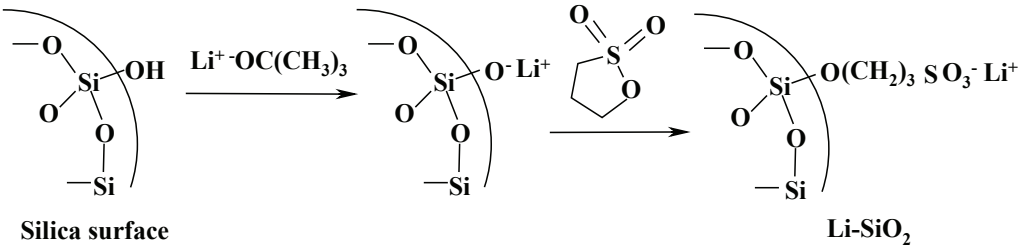
It has been found that the development of surface functionalised electrodes requires suitable binding groups. We have been investigating the use of both amino groups and carboxylic acids for the binding of monolayers of small molecules such as ferrocene.

Milestone 9: Preparation of functionalised inorganic nanoparticles and nanofibres for P2 and P3 (end Year 3).
Refined: Extend to end of Year 4

Lithium modified silica (Li-SiO_2) nano-particles were synthesized (Fig. 23) and gel electrolytes containing these nano-particles were prepared and characterized. These particles have been supplied to Prof Liu's group to prepare lithium conductive polymer films.

Functionalised silica nano-particles synthesized:

Figure 23



(i) proton conductive silica; (ii) quaternary ammonium iodide-silica; and (iii) imidazolium iodide-silica. (ii) and (iii) will be used in Prof Cheng's group for the solar cell project.

Milestone 10: Prepare ICP-coated inorganic nanostructures for P3 (end Year 3 then ongoing).

Refined milestone: Prepare ICP-coated inorganic nanostructures for P2 and P3 (end Year 3 then ongoing).

Processing

Milestone 11: Establish wet-spinning fibre drawing facilities (end Year 1).

We have successfully identified the key requirements for efficient wet-spinning of organic conducting fibres, based on interesting conducting polymers and/or carbon nanotubes. The "counter current" wet spinning coagulation system originally developed at UT Dallas was refined and established in our laboratories.

Conducting polymer-Carbon nanotube fibres with the highest combination of conductivity and mechanical strength reported to date have been produced. We have also produced carbon nanotube biomolecule composite fibres with a combination of the highest conductivity and mechanical properties reported to date.

With the optimised spinning parameters, we have effectively spun various fibre types and compositions of highly electrically conducting and biologically friendly fibres including combinations from inherently conducting polymer (i.e., polyaniline and polypyrrole) and biopolymers (hyaluronic acid, chitosan, DNA, heparin, etc.) with carbon nanotubes.

We have identified and tested a fully automated lab-scale spinning-drawing machine that is currently being manufactured in Japan that will be acquired early 2007.

Milestone 12: Prepare functionalised aligned CNTs for P2 and P3 (end Year 1 then ongoing).

Refined milestone: 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.

In 2006, progress has been made towards this milestone on several convergent research fronts. A key piece of equipment has come online during 2006 allowing more control during and reproducibility of the Chemical Vapour Deposition (CVD). A fully automated thermal CVD integrated system was purchased from Atomate (Santa Barbara, USA) and installed in February 2006. The procedures used previously for preparing aligned nanotube forests have been optimised and successfully transferred to the new equipment. Samples of controlled length and controlled tube density have been produced.

The simplest route to "functionalising" aligned carbon nanotubes has been adopted during 2006. This involves imbibing functional molecules into the interstitial volume between the tubes.

To date bio materials such as poly(styrene-beta-isobutylene-beta-styrene) (SIBS) and conducting polymers such as PEDOT have been integrated. This approach will be used to provide the functionalised carbon nanotube arrays, required for P2, P3 and P4 and specified above during 2007. Attempts to covalently functionalise CNTs (see Program Milestone 1) have highlighted the significant challenges to be overcome here.

Our success in non-covalent (see Milestone 3) functionalisation will be used here in producing novel aligned CNT arrays for Energy Conversion, Energy Storage and Bionics.

Milestone 13: Establish sol-gel methods for self assembly (end Year 2).
Refined: To be combined with Milestone 9.

Milestone 14: Supply of fabricated structures to P2-P4 (end Year 2 then ongoing).

As outlined above, aligned carbon nanotube structures are being supplied for Energy Conversion, Energy Storage, and Bionics Programs.

Conducting polymer-CNT composite fibres have been supplied for artificial muscle investigations.

Functional electrolytes

Milestone 15: Develop and characterise enhanced performance electrolytes including plastic and solid gel electrolytes (end Year 2).
Refined: Extend to end of Year 4.

Polyelectrolyte gels based on Poly(LiAMPS) and Ionic liquids/Ionic Liquid mixtures of N,N-methyl propyl pyrrolidinium (NTf2) and ethylmethyl imidazolium mesylate were prepared in order to achieve high lithium ion transport. The effect of ionic liquid mixtures was investigated from the perspective of 'ionic confusion' leading to more possibilities of lithium ion coordination and hence a greater likelihood of dissociation of the lithium from the backbone polymer. The mixed IL solvents did lead to higher lithium ion compatibility and higher lithium ion diffusion in the gel electrolytes.

Plastic crystal electrolytes based on pentaglycerine molecular plastic crystals were investigated as host materials for acids in order to achieve high proton conductivity. Several orders of magnitude enhancement of conductivity was achieved even with 1mol% acid doped into the pentaglycerine matrix. Cyclic Voltammetry on platinum indicated that the proton was active in these electrolytes.

Another exciting discovery involves the use of electric field to induce order in plastic crystals (Fig. 24).

A significant conductivity enhancement has been observed in pyrrolidinium based plastic crystal electrolytes upon application of a 4V field during crystallisation from the melt. Optical microscopy and powder XRD suggest ordering and preferential orientation may be responsible for this increased conductivity.

Milestone 16: Develop and characterize highly conductive zwitterion based electrolytes (end Year 3).

The effect of Zwitterion addition to a number of polyelectrolyte and Ionic Liquid systems has been investigated. The ability to achieve enhanced lithium ion diffusion is highly dependent on the anion present either on the polyelectrolyte backbone and/or the anion in the Ionic Liquid solvent. In addition, the solvent used in the polymer gel electrolytes is critical in achieving a zwitterion enhanced conductivity.

Ab Initio calculations have been applied to explain some of the contradictory effects observed with the addition of zwitterions. Using ab initio theory we calculated a handful of complexes that the lithium cations may form with traditional solvents such as DMSO, PEO, EC and DMA as well as ionic liquids (TFSA-based, mesylate-based and acetate-based). The binding energies of these complexes are compared to those of the anionic polymer backbone with Li^+ ions. We were able to establish the relationship between the solvation processes, i.e. the Li^+ ions dissociation from the polymer backbone with help of solvent molecules and addition of zwitterion containing either the sulphonate or carboxylic negatively charged terminal groups. The conductivity of the polyelectrolyte systems when zwitterion is added strongly depends on the solvating ability of solvents. In the case of the "strongly-solvating" solvents such as DMSO, mesylate- and acetate-based ionic liquids, a large portion of the lithium cations have already

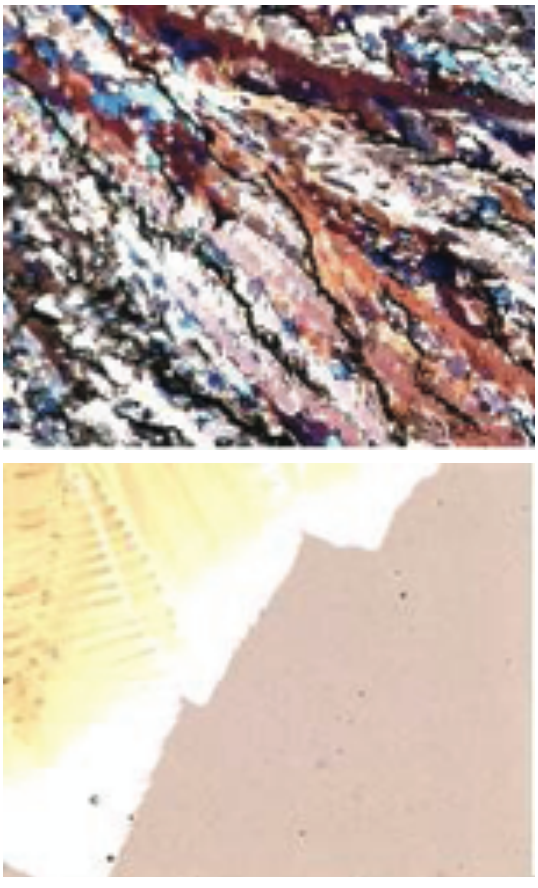


Figure 24: The upper image shows the crystalline morphology of the plastic crystal when cooled from the ionic liquid without the application of an electric field. It can be seen that there is much anisotropy both in size and direction of the crystals. The lower optical image shows the crystal morphology of the plastic crystal when cooled from the ionic liquid with 4V applied. It can be seen that the anisotropy is now absent, with large crystals present.

dissociated from the polymer backbone leaving zwitterion no chance of enhancing the dissociation. In case of "poorly-solvating" solvents such as EC, DMA, PEO and TFSA-based ionic liquids, zwitterion does help to enhance the Li+ dissociation, as these solvents cannot offer a stronger interaction to the lithium cations compared to the anionic polymer backbone. To this end, the role of zwitterion in poorly-solvating solvents is to enhance the Li^+ dissociation from the anionic polymer backbone. This work has been presented at ISPE10 (international symposium on polymer electrolytes) and is the subject of a manuscript in preparation.

Milestone 17: Prepare new functionalised nanoparticles for incorporation into gel electrolytes (end Year 3).

Work not yet commenced.

Milestone 18: Develop and characterise nanocomposite electrolytes containing functional fillers (end Year 3).

The influence of nanoparticles of SiO_2. Al_2O_3 and TiO_2 on the transport and mechanical properties of N,N-methyl propyl pyrrolidinium NTf2 have been investigated and it was shown that several orders of magnitude increases in conductivity is possible when just 6vol% of SiO_2 is incorporated. Electron microscopy and positron annihilation lifetime spectroscopy has shown the enhanced plasticity in these materials resulting from strain induced defect formation in the nanocomposites.

Milestone 19: Supply/refinement of electrolytes for P2-P4 (end Year 2 then ongoing).

For P2 requirements, see milestones 27 and 32.

For P3 requirements, see milestone 36.

P4 requirements – biocompatible electrolytes for bio batteries.

P1-2 Characterisation

Milestone 20: Establishment of co-ordinated characterisation users' network (end Year 2).

A detailed list of equipment, location and nominated trainers has been compiled.

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).

A number of in-house training courses have been delivered. Centre staff also obtain training on specialised spectroscopy techniques as part of a UoW arrangement with NanoMNRF. Acquisition of other equipment through joint ventures with BlueScope Steel (SECM) and CRC Polymers (Solar simulator) was accomplished.

Milestone 22: Utilisation of novel characterisation tools in P1-P4 (ongoing).

Various techniques have been developed to aid in the characterisation of reactive metal surfaces. A substantial effort has been devoted to the development of a micro-capillary electrochemical cell (Fig. 25) which enables discrete measurements to be performed on micrometer scale regions of the surface.

In collaboration with IWRI and La Trobe University, X-ray Photoelectron Spectroscopy (XPS) and Time of Flight –Secondary Ion Mass Spectroscopy (ToF-SIMS) have been explored for use in characterising thin films on metal surfaces. Both techniques have been investigated for their ability to provide depth profiling as well as imaging of surface species distribution.

Figure 25: The micro capillary electrochemical cell.

Appendix I: Milestones Report

Microscope Raman Spectroscopy for characterisation of inhibition mechanisms on reactive metals: To characterise the interaction of novel rare earth organophosphate inhibitors with aluminium alloys in a corrosive environment.

Protective films are extremely thin, and were not able to be detected using EDXS. 2D Raman mapping of the alloy surface (Fig. 26) after immersion in inhibitor solutions provided evidence for the presence of the inhibitor on the surface. The Raman capabilities available at UoW have been used.

Correlation of the deposition patterns displayed in Raman maps of the alloy surface with optical micrographs of the mapped area provide information on the mechanism of corrosion inhibition as well as evidence of inhibitor presence on the alloy surface. This information can be used in conjunction with electrochemical testing techniques to support the proposed mechanisms.

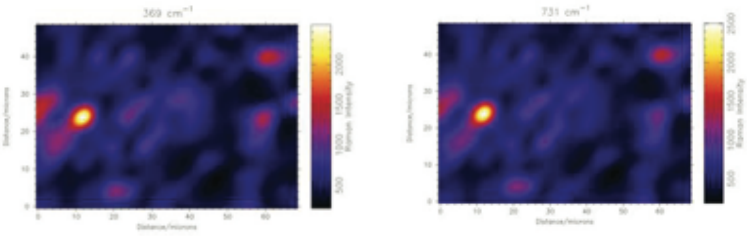


Figure 26: Examples of Raman maps generated from AA2024-T3 immersed in cerium diphenyl phosphate and sodium chloride. The Raman shifts correspond to Ce-O and the symmetric vibration of υ_SO-P-O. Areas of high intensity and the deposition pattern are similar, indicating the inhibitor complex is present on the surface.

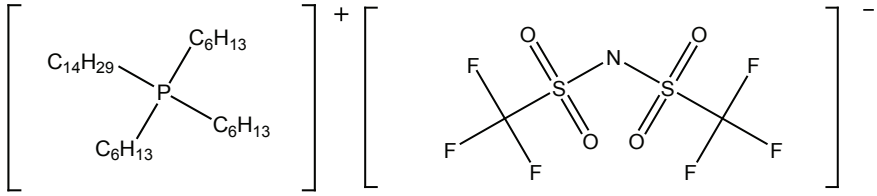
Milestone 23: Characterisation of reactive metal interfaces to develop understanding of interfacial phenomena at electromaterials interfaces and in applications including corrosion, electrowinning and energy storage and conversion (ongoing).

The principle efforts in this area have focused on the metal | ionic liquid (IL) interface. Specifically, two ionic liquids (based on two different anions) have been chosen. The first IL (Fig. 27), trihexyl(tetradecyl)phosphonium bis(trifluoromethanesulfonyl)amide ($P_{6,6,6,14}$TFSA), has been investigated extensively for its film formation properties on reactive metals and this work has resulted in several recent publications.

The publications deal mainly with the corrosion resistant properties of the IL generated film in terms of its electrochemical characterisation. Spectroscopic data is reported which details the composition and structure of the surface film formed on lithium and a detailed investigation into the reaction mechanism (which is dominated by the TFSA anion) is reported. A paper is being drafted which will report XPS, ToF-SIMS, EIS and NMR characterisation of the film formed on magnesium alloy AZ31.

The second IL, trihexyl(tetradecyl)phosphonium bis 2,4,4-trimethylpentylphosphinate

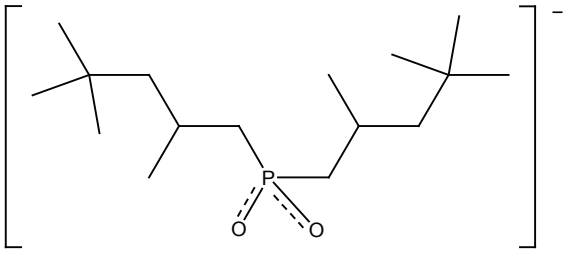
Figure 27



trihexyl(tetradecyl)phosphonium bis(trifluoromethanesulfonyl)amide

($P_{6,6,6,14}$M3PPh) (Fig. 28) has also been found to form protective passivation film on magnesium alloy AZ31, a publication describing the electrochemical characterisation of the film poroperties has been submitted. Preliminary spectroscopic characterisation (XPS and ToF-SIMS) of the film indicates that the anion remains intact on the surface (in contrast to the TFSA anion which decomposes to it substituents). The film is also indicated to be very thin, possibly less than 50nm.

Figure 28



bis 2,4,4-trimethylpentylphosphinate

P1-3 Modelling

Milestone 24: Simulate model electromaterials and processes (end Year 3).

Simulate made electromaterials

The activity relating to this milestone has been directed towards the modeling and simulation of the mechanical response produced from electromechanical actuators, as an example of an electromaterial system. Modeling the mechanical response involves a mathematical description of the electrochemical cell and a mathematical description of the mechanical response (stress and/or strain) of the electrode material. The research has mainly focused on the latter by including time – dependent responses into existing models. The conducting polymer actuators of interest to the Centre are activated by small voltages, but produce quite large visco-elastic responses. We have studied the origin of these slow responses and built simulation models that include the viscoelasticity of the material. Secondly, the effect of the geometry of the actuator has also been considered and modeled as it affects the magnitude of the movement and force produced.

Ionic Liquids and other electrolyte materials

Ab initio methods have been developed and applied to the study of ionic liquids and other electrolyte materials. Specifically much has been learnt about the commonly used bis(trifluoro sulfonamide) anion. Optimisation of the reduced TFSA anion ($N(SO_2CF_3)_2^{2-}$) ended in breaking one of the S-N bonds. As a result, two species were formed: an anion, $SO_2CF_3^-$, and a nitrogen-centred radical, $N\bullet SO_2CF_3^-$.

The reason for such an interesting phenomenon lies in the electronic configuration of the TFSA anion (Fig. 29), which can be explained by examining the total electron density (a) and the lowest unoccupied orbital (LUMO) (b). The total electron density was plotted together with the molecular electrostatic potential values that indicate where the electrostatic potential takes negative and positive values. It is clearly seen that the TFSA anion represents a very diffuse anion, with the electron density being spread over the whole molecule. This observation allows us to assume that the nitrogen atom has only a partially negative charge and hence may be reduced in an electrochemical process. The theoretical calculations for anion reduction and oxidation processes compared favorably with the actual measured electrochemical window as seen on the right.

Milestone 25: Integrate advanced characterisation and theory for material development (end Year 4).

Ab Initio calculations have been applied to explain some of the contradictory effects observed with the addition of zwitterions. See Milestone 16 for greater detail.

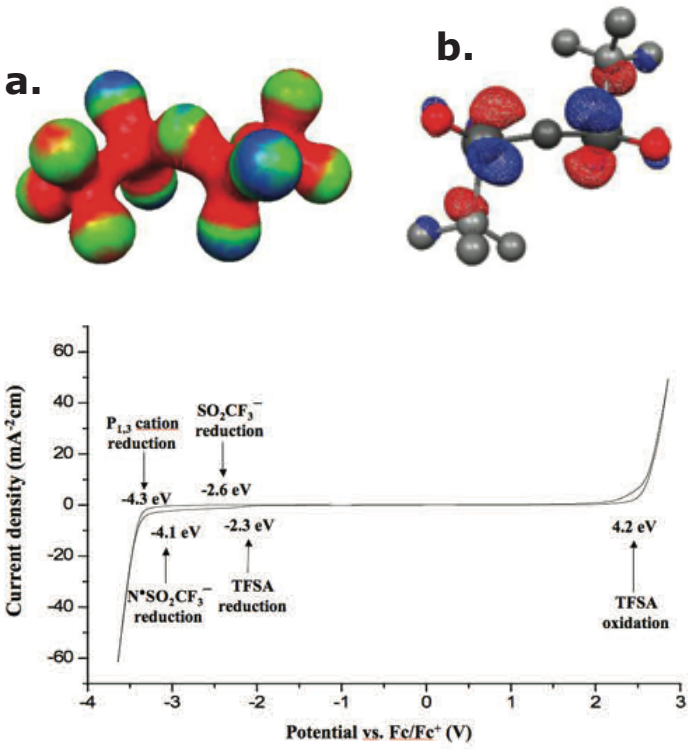


Figure 29: Electrochemical window: theory versus experiment.

Appendix I: Milestones Report

P2. Energy Conversion

P2-1 Solar Energy Conversion

Milestone 26: Develop nanostructured photoelectrochemical solar cells with >5% efficiency (end Year 3).

New dyes

Following the achievement of a 6.7% solar cell efficiency (see below) with the porphyrin tolyl derivative (WMC273) in November 2005, we have been able to increase this in 2006 to 7% using the porphyrin xylyl malonic acid in the laboratories of our Swiss collaborators at the École Polytechnique Féderale Lausanne (Fig. 30). These small incremental changes are typical of the achievements in this area and this is a world record for porphyrin dyes.

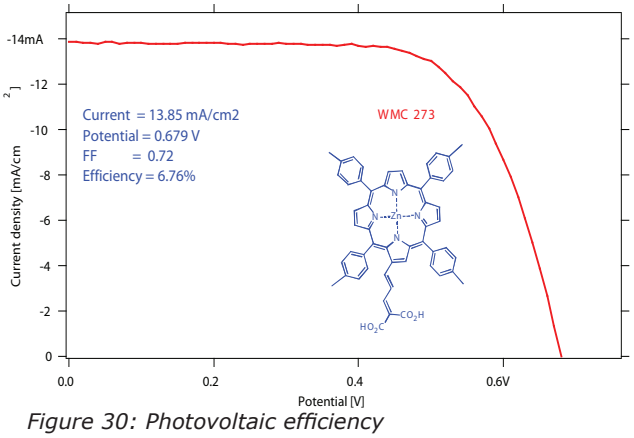
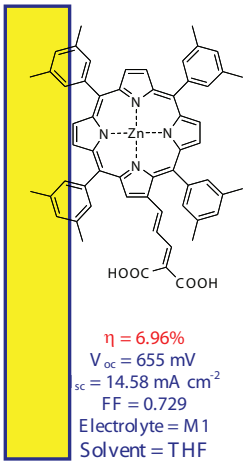


Figure 30: Photovoltaic efficiency



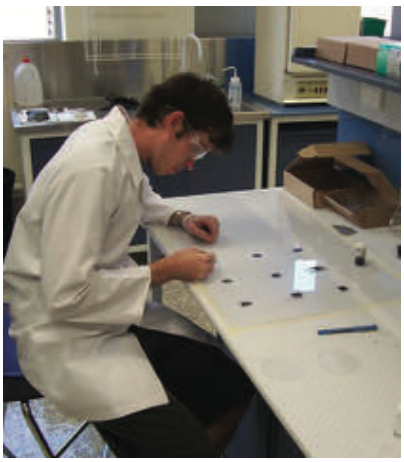


Figure 31: ACES researcher 4th Year Monash student Michael Ferguson preparing nanostructured photoanodes.

Figure 32: Example of a flexible dye-sensitized solar cells based on a plastic solid electrolyte material and TiO_2.

Milestone 27: Develop nanostructured solid state polymer (electrolyte) solar cells with >4% efficiency (end Year 4).
Refined to: Develop nanostructured solid state solar cells with >4% efficiency (end Year 4).

Flexible dye-sensitized solar cells (FDSSCs) based on a plastic solid electrolyte material and TiO_2 on a plastic substrates have been prepared (Fig. 32). The best performing FDSSCs devices gave gravimetric power densities of 18 mWg^{-1} at 100 $mWcm^{-2}$ (1Sun) incident power, which is more than twice that of state of the art glass-based DSSCs (approximately 9.6 mWg^{-1}). These power densities are considered to be the critical property of solar cells for a variety of portable applications. Efficiency is around 1% at this stage and improvements are expected.

Milestone 28: Develop nanostructured self-assembled photoanodes for integration into both solar conversion cells (end Year 5).

Working p-type photocathodes have been produced. These are based on Nickel Oxide, and have been incorporated into liquid DSSCs along with both inert platinum counter electrodes and titanium dioxide photoanodes - to create tandem DSSCs. At present the best efficiency realised for NiO electrodes is roughly 0.021%, which is close to the best reported value of 0.027%.

New electrodes

A method was developed to produce nanostructured nickel (II) oxide electrodes based on commercial NiO nanopowders. The method was optimised in terms of sintering conditions (time, temperature), layer thickness and polymer content.

13 different sensitisers were screened for their applicability in dye-sensitised photocathodes. Coumarin 343 was found to be the most efficient sensitizer.

Different electrolyte compositions were tested. Using optimised conditions short-circuit currents of up to 2.9 $mA.cm^{-2}$ were realized. This exceeds values reported in literature by almost a factor of 3. Internal photon to electron conversion efficiencies reached close to 50%.

P2-2 Electromechanical Actuators

Milestone 29: Establish basic mechanisms of gel adhesion to electrodes (end Year 1).

The work related to this milestone has been mainly concerned with developing an understanding of the adhesion of ionic gels to charged and uncharged substrates. Both anionic and cationic gels have been synthesized and their adhesion to each other and to oppositely charged substrates has been measured. The adhesion is found to be highly dependent on the pH and the ionic strength of the environment, as it is caused by 'counter-ion evaporation', that is the free energy, mainly entropy, change when a polymeric counter-ion is exchanged for a small molecule counter-ion, releasing the small molecule counter-ion into the solution.

At neutral pH and at low ionic strength the adhesion is strong enough to cause cohesive failure within the (untoughened) gels. As gels with high adhesion need also to be tough (as do gels that are useful as actuators) it has proved essential to gain an understanding of the techniques for making tough gels. To this end a collaboration has been initiated with Prof J. P. Gong of Hokkaido University whose group has developed tough, double network gels. A theory of the mechanism by which the existence of the two networks toughens of these double network gels has been developed and submitted for publication. Some of its predictions are currently being tested.

Milestone 30: Develop phenomenological models of ICP and gel actuation under low voltage electrochemical stimulus, taking into account the influence of ion movements, osmotic effects, chain conformation changes and changing mechanical properties (end Year 2).

Most activity relating to this milestone has involved the study of the effect of modulus changes on the degree of actuation produced by electrochemical stimulation for ICPs and pH stimulation for gels. A reversal in the direction of actuation (shrinkage rather than expansion) was noted for gel actuators operating under a constant compressive load (as would occur in some valve designs). This surprising behaviour was mostly explained by a change in gel surface friction and published in *Nature Materials*.

More recent studies have focused on gel fibres operated in tension with the application of rubber elasticity theory used to describe the behaviour at different tensions. This theory is being modified to include the effect of polymer charge and further studies using the synchrotron facility in the USA (in collaboration with Dr Robert Knott and ANSTO) have been conducted. Meanwhile, several studies involving the introduction of carbon nanotube reinforcement to ICP and gel actuators were completed and published. These studies show that the influence of modulus shift during actuation can be restricted by the addition of CNTs. Finally, one study has also shown that the modulus shift in polythiophene actuation produces larger strains when higher stresses are applied- this is the opposite behaviour to observed in all other systems.

Milestone 31: Develop artificial muscles with 5% strain at loads up to 10 MPa and strain rates of >10% sec^{-1} (end Year 3).

Considerable improvement in the speed of response of ICP–based artificial muscles has been achieved recently. We have produced bending type actuators that show measurable bending actuation to 90 Hz and demonstrate mechanical resonance (large amplitude bending) at around 8-10 Hz. Similarly fast actuation has also been demonstrated for carbon nanotube sheets and published in *Advanced Materials*. Another paper in the same journal demonstrated actuation at the highest applied stress (125 MPa) for carbon – nanotube reinforced polyaniline fibres.

Milestone 32: Develop electrochemical pneumatic actuators using nanostructured electrodes and electrolytes (end Year 5).

Activity relating to this milestone has focussed on the evaluation of different electrode materials for the generation of pneumatic pressure. Progress included the development of suitable test methods; determination of the most suitable electrolyte system; evaluation of various CNT electrodes and electrochemical stimulus conditions.

P2-3 Nanostructured Electroluminescent Materials

Milestone 33: Develop and demonstrate energy efficient nanostructured electroluminescent devices (end Year 3).

Work not yet commenced.

Milestone 34: Optimise materials in nanostructured electroluminescent devices (end Year 5).

Work not yet commenced.

Appendix I: Milestones Report

P3. Energy Storage

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

Milestone 35: Develop nanostructured materials for electrode in Li-ion rechargeable battery (end Year 3).

Carbon-coated Si nanocomposites produced by a spray-pyrolysis technique (Fig. 33), which can reversibly store lithium with both a high capacity of 1489 mAh.g^{-1} and a high coulombic efficiency above 99.5%, even after 20 cycles. The spray-pyrolysis method used in this study is instantaneous, versatile, inexpensive, industrially oriented, and can be operated over a large temperature range (150–1400^{o}C).

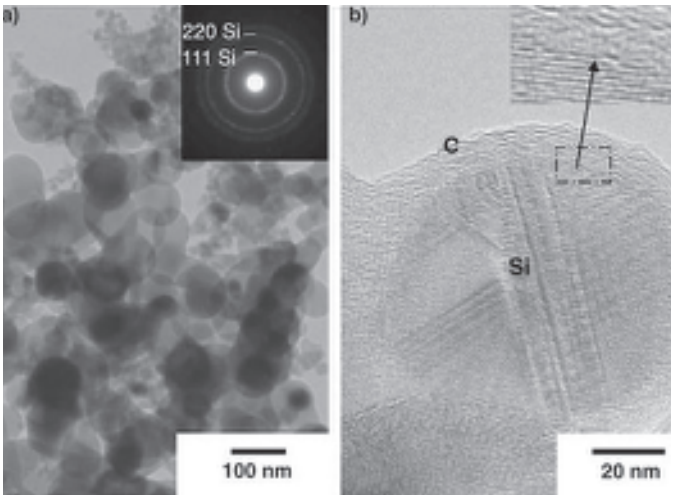


Figure 33: TEM images of spheroidal carbon-coated Si nanocomposites produced by spray pyrolysis in air: (a) low-magnification image of a sample produced at 400^{o}C, with the indexed diffraction pattern (inset) confirming the presence of Si nanoparticles; (b) high-resolution image showing the carbon-coated Si nanocomposite, with the inset showing the interface between a crystalline Si particle and the pyrolyzed carbon coating layer (ca. 10 nm thickness).

Spray Pyrolyzed PbO-Carbon Nanocomposites as Anode for Lithium-Ion Batteries

A new approach has been used to prepare nanostructured lead oxide-carbon (PbO-C) composites via the spray pyrolysis technique. The electrochemical performance of the PbO-carbon nanocomposites as anode materials for lithium-ion rechargeable batteries was investigated. The prepared powders consist of fine nanocrystalline PbO homogeneously distributed within an amorphous carbon matrix with highly developed surface area. The estimated average crystal sizes of these nanocomposites from X-ray diffraction patterns are in the range of 26–102 nm.

The combination of spray technology and carbon addition increased the specific surface area and the conductivity of PbO, improved the specific capacity, and maintained cycle life with a reversible capacity above 100 mAh.g^{-1} beyond 50 cycles. The increase in capacity retention for PbO-carbon compared to that of pure PbO was due to the presence of a conductive and highly developed carbon matrix that can absorb large volume changes during the alloying/dealloying of lead with lithium over the 1.50 to 0.01 V potential range, which yields LixPb alloys (0<X<4.5).

Co_3O_4–C composite as anode materials in Li-ion batteries

Co_3O_4–C composite powder has been synthesized via spray pyrolysis of cobalt nitrate-sugar solution at 600°C and assessed for application as anode materials in Li-ion batteries. Microstructural characterization by scanning electron microscopy, transmission electron microscopy, and energy-dispersive X-ray spectroscopy confirm an even distribution of carbon throughout particles, as well as the presence of a carbon-based surface sheath surrounding Co_3O_4–C particle agglomerates. Charge-discharge cycling of half-cells indicates a stable reversible discharge capacity above 800 mAh.g^{-1}.

Si-DC nanocomposites evaluated for use in Li Ion batteries

A large irreversible capacity and a large hysteresis between charging and discharging curves can be observed from the typical charging/discharging curves of the Si–DC nanocomposites, which is typical for silicon-based electrodes. It is found that the electrochemical performance of the Si–DC nanocomposites is significantly influenced by the pyrolysis conditions of the sample production. The sintering temperature, the heating rate, the argon flow rate and the morphology of the PVA all affect the final products.

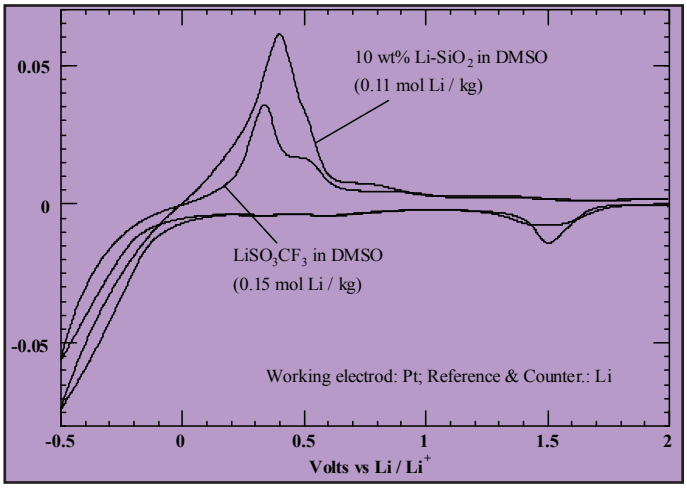


Figure 34: Cyclic voltammogram for the Li-SiO_2/ DMSO gel sample at room temperature indicating stable plating and stripping of Li metal.

Milestone 36: Develop polymer electrolytes for advanced lithium-ion batteries (end Year 3).

Several discussions have been initiated between the Monash Electrolytes researchers and Prof Liu's battery team in Wollongong. A number of systems were identified for trialling in the first instance. Specifically, Lithium modified silica (Li-SiO_2) nano-particles were synthesized and gel electrolytes containing these nano-particles were prepared and characterised. These particles were used in Prof Liu's group to prepare lithium conductive polymer films for this lithium battery milestone.

Lithium modified silica (Li-SiO_2) nano-particles were used to prepare gel electrolytes with different solvents, including an ionic liquid (P_{13}TFSA). These gel materials were characterized by conductivity measurements, DSC, CV (see Fig. 34 on previous page), and solid state NMR.

Milestone 37: Investigate the capacity loss and rechargeability of thin film anodes (end Year 3).

Electrochemical properties of Si thin film prepared by pulsed laser deposition for lithium ion micro-batteries

The microstructure and morphology of the films were characterized by scanning electron microscopy, X-ray diffraction and atomic force microscopy. The anodic electrochemical performance of the films was examined in the range of 0.005–1.5V, which revealed excellent cyclic stability without any large capacity fade up to the 70th cycle. The PLD process was suitable for improving the density and adhesion behavior of the films.

Mesoporous Au film as anode material for Li-ion battery

The morphology of the Au was characterised by interconnected pores and channels of between 5 and 20 nm in diameter. This is the first time for the use of these films as an electrode in Li rechargeable batteries. It was found that the Li alloying processes occurred in the voltage range of 0 to 0.25 V, while de-alloying occurred in two stages at about 0.15 and 0.45V. This is significantly lower than in the Li–Sn or Li-Sn-Cu systems (0.2-1.0V) but comparable to that reported for thin, solid gold anodes.

Overall, a multilayer mesoporous Au film showed superior characteristics compared to an ordinary Au film, with a higher specific charge passed. Capacity of all electrodes tested was of the order of 500 $mAh.g^{-1}$ during the initial discharge cycle, but was subject to a steep fade during subsequent cycles. The capacity of the multilayer, mesoporous gold settled at about 80 $mAh.g^{-1}$ after 30 cycles, while that of the ordinary Au film fell to about 10 $mAh.g^{-1}$.

Milestone 38: Develop chemically stable and structurally stable thin film cathodes (End Year 4).

Crystalline $LiFePO_4$ was made in only 10 min via a versatile process of Electric discharge assisted mechanical milling (EDAMM). Preliminary electrochemical testing of the synthesized powder demonstrates good capacity and excellent cyclability. The EDAMM technique offers an exciting opportunity to synthesize a range of new and existing materials to be used in a variety of energy storage applications that include rechargeable lithium batteries, hydrogen fuel cells, and supercapacitors.

Milestone 39: Develop long life, high energy density all solid-state thin-film Li-ion microbatteries (end Year 5).

Work not yet commenced.

Appendix I: Milestones Report

P3-2 Advanced Metal Batteries

Milestone 40: Develop highly conductive nanocomposite electrolytes and electrodes for metal battery applications (end Year 3).

Doped PANI nanostructures in Li/ PANI rechargeable batteries

Poly(aniline) nanotubes and nanofibres have been prepared through a template route (Figures 35 and 36) and a spray technique (Figures 37 and 38), respectively. The as-prepared poly (aniline) nanotubes exhibit higher electrical conductivity, larger charge–discharge capacity, and better cycling capability than commercial available PANI powders when used in Li/PANI rechargeable batteries.

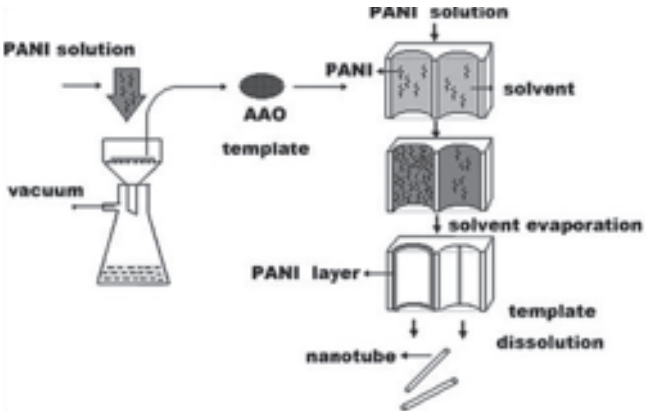


Figure 35: Schematic diagram showing the porous-alumina-template synthesis of HClO4-doped PANI nanotubes.

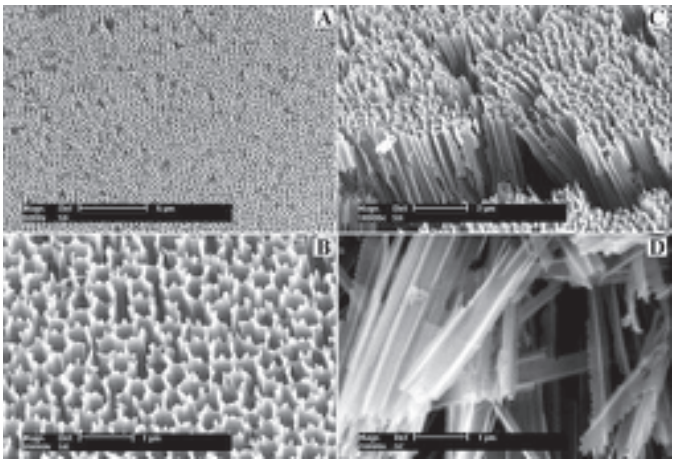


Figure 36: SEM images of the $HClO_4$-doped PANI nanotubes in ordered alignment: (A) typical overall view of the tips showing the comb-like structure; (B) top view at high magnification; (C) side view showing the walls of the tubes; (D) vertical cross-section of the tubes after ultrasonic treatment.

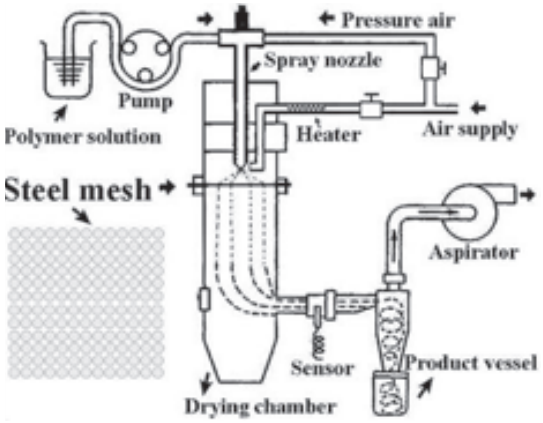


Figure 37: Schematic depiction of the large-scale synthesis of $HClO_4$-PANI nanofibres through a spray technique.

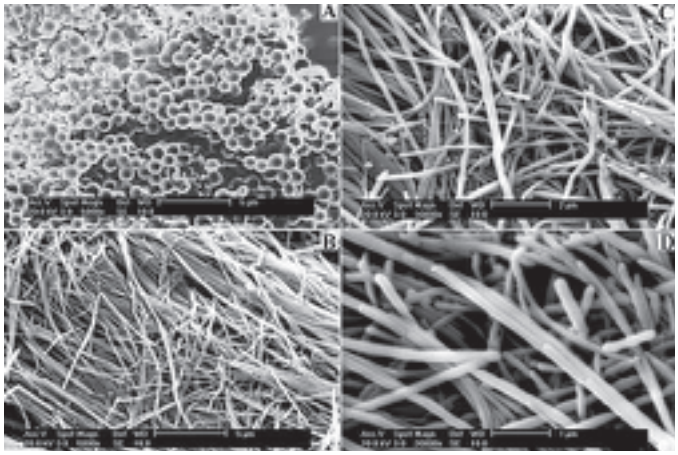


Figure 38: SEM images at different magnifications of the $HClO_4$-PANI nanofibres produced by the spray technique: (A) without; and (B, C, D) with the use of steel mesh.

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).

Detailed studies of the electrode | electrolyte interface in lithium cells has been undertaken. In lithium cells a passivation film, known as the Solid Electrolyte Interphase (SEI), is formed on the electrode surface. The SEI performs a dual role of protecting the lithium electrode from corrosion while still allowing lithium transport to facilitate charging and discharging of the device. The work has focused on the SEI formed in ionic liquid (IL) electrolytes based on the bis(trifluoromethanesulfonyl)amide anion. A detailed report of Diffuse Reflectance – FTIR, EIS, XPS and Raman spectroscopic characterization has recently been published (publication 48 in Appendix X). A more recent report describes the breakdown of the TFSA anion on a range of substrates and reports the influence of trace amounts of water on the rate of the breakdown process (publication 56 in Appendix X). Ab-initio calculations are used to provide insight into the likely mechanism of the process which correlates well with the observed electrochemical behaviour.

P3-3 Organic Batteries

Milestone 42: Develop an all-polymer battery with capacity of 80 mA.h.g^{-1} using nanostructured materials from P1 (end Year 3).

The development of an all-polymer battery has continued with the investigation of the formation of electrochemically polymerised poly(dialkoxyterthiophene) anodes (Fig. 39) onto a variety of substrates and their use with polypyrrole cathodes. While a poly(OC_{10}STT) anode exhibited a maxium discharge capacity of 94.7 mAh g^{-1} in contrast to a discharge capacity of 45.2 mAh g^{-1} for a poly(OC_{10}DASTT) anode, both on Ni/Cu fibre mat, discharge capacity decreased for both polymers with charge/discharge cycling.

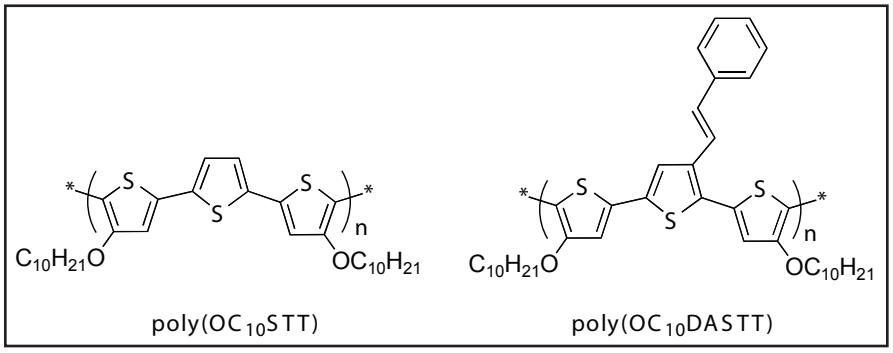


Figure 39: Polymers used for plastic anodes.

Milestone 43: Develop an all-polymer capacitor with capacity of the order of 100 F g^{-1} (end Year 3).

Charge carrier "super-mobility" has been discovered in vapour phase polymerised PEDOT materials by Dr Bjorn Winther-Jensen. Conducting polymers prepared by a templated vapour phase polymerisation process involving solid phase transition metal complexes are found to produce polymers with charge carriers that exhibit maximum drift velocity considerably greater than copper. This super-mobility seems to be related to a greater degree of ordering in the material chains as evidenced by the X-ray diffraction data. This may result from a templated polymerisation process.

The high mobility manifests itself as a capacity to sustain very high conductivities and current densities (>10000A.cm^{-2}) as shown in Figure 40; such high current densities are of importance in thin film conductor applications. Specific capacitance of these materials is already high (60 F.g^{-1}) and there is considerable scope for optimisation. These materials have potential to be optimal conducting polymer materials for organic battery and super-capacitor applications.

Milestone 44: Develop fabrication techniques for flexible membrane structures utilising these materials (end Year 3).

A novel hollow fibre membrane structure has been produced.

Milestone 45: Develop wet-spinning techniques that enable the use of wet-spinning to produce fibre batteries and supercapacitors (end Year 4).

Preliminary work has commenced.

Milestone 46: Integrate fibre batteries

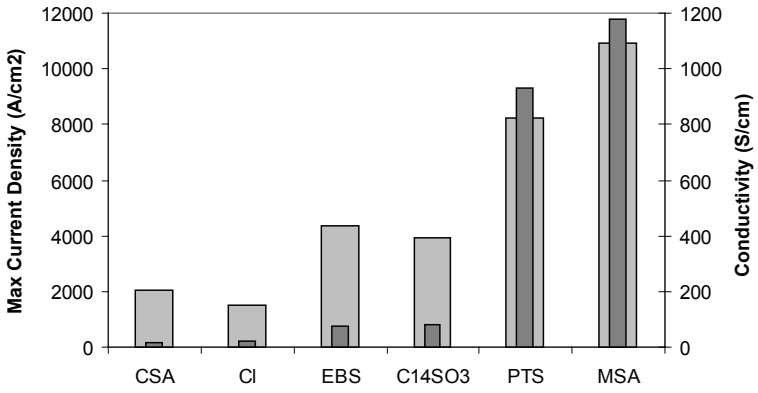


Figure 40: Current density and conductivities of vapour phase polymerised PEDOT materials.

into textile structures (end Year 5).

Work not yet commenced.

P4. Bionics

P4-1 Nerve Cell Communications

P4-2 Bio-stability and Biocompatibility

Milestone 47: An understanding of the interfacial chemistries required for efficient cell adhesion and cell proliferation (end Year 1).

Milestone 48: An understanding of how energy transfer processes (electrical, optical stimulation) influence these interfacial chemistries (end Year 2).

Electrochemical cell prototypes to enable detailed studies to be carried out have been produced.

Understanding the interfacial chemistries for efficient cell adhesion and proliferation to electroactive polymers has application for improved cochlear implant hearing prostheses, and the restoration of spinal cord function.

The research in the Bionics program has demonstrated the electrical stimulus parameters for the uptake and release of the protein NT-3 for nerve preservation and growth (Figure 41). The electrical parameters that are essential for the safe transfer of electrical energy for neural stimulation are also effective for the release of NT-3. In addition, the research is showing that the dopants used to develop the polymer have a significant effect on NT-3 uptake and release.

The adhesion of neurites to the polymer is important for cell growth, and in particular the extension of the neurite processes (axons and dendrites). It has been shown that the adhesion varies depending on the dopant, as well as a film containing adhesion molecules.

The surface topography of the polymer may influence neuronal extension and is being controlled in further studies (Figure 42). The interaction between neurite and polymer is being further investigated using Fourier Transform Infra-red Spectroscopy.

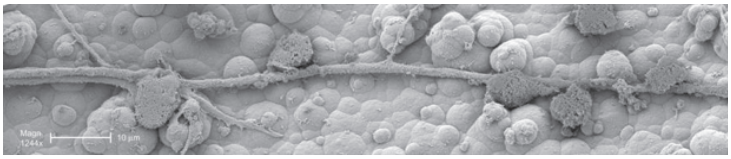


Figure 42. High magnification of a hearing nerve growing on polypyrrole was achieved with a scanning electron microscope. It demonstrated that nerves make good contact with the nodular surface of polypyrrole.

The interfacial chemistry is being modelled, and in particular to determine the effect of hydrophobicity on the uptake and release of NT-3. Research is in progress to develop invitro tank studies to specifically investigate the effect of stimulus parameters such as current strength and density on neural growth. In addition, the research is in progress to produce configurations of carbon nanotubes to be used with polypyrrole and nerve growth factors as preliminary research for Milestone 49. This involves biocompatibility, invitro and invivo stimulus and release studies and the application to experimental animal models.

Milestone 49: Utilise and refine fibre fabrication protocols (P1) that allow for production of micro-devices to control the direction of neurite outgrowth (end Year 3).

Devices designed – yet to be built

Milestone 50: Develop nanofabrication protocols that allow construction of 3-dimensional networks and devices for integration with fibrous tissue as well as

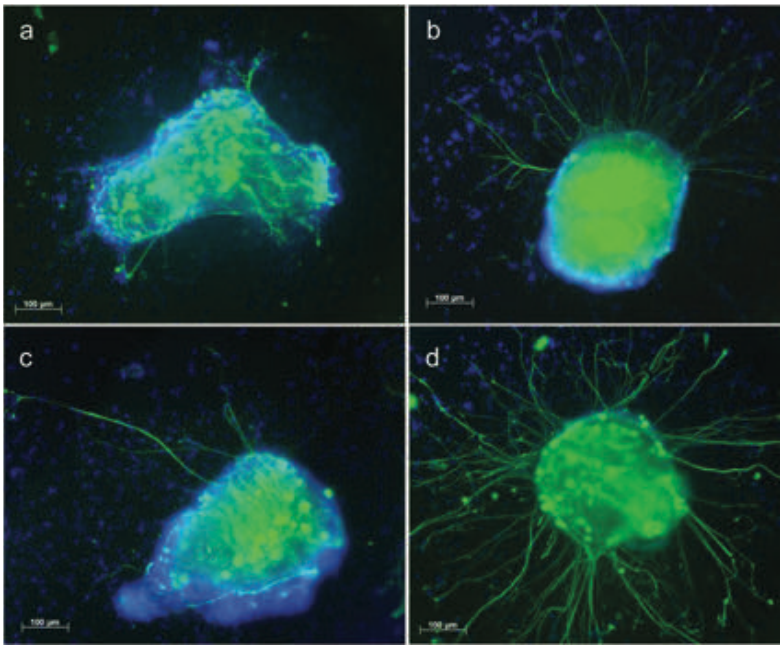


Figure 41: Inner ear nerve tissue grown on plain polypyrrole shows poor nerve outgrowth (a). A coating of cell adhesion molecules to plain polypyrrole (b) or incorporation of NT3 into the polymer (c) improves nerve outgrowth from the tissue. However, more extensive nerve growth is observed when nerve growth factors are incorporated into polypyrrole and a cell adhesion coated is applied (d).

cell adhesion and proliferation (end Year 5).

Work not yet commenced.

P5. Ethics

P5-1 Biosystems, Electromaterials and Commodification of Human Health

The ethics research program is yet to commence.

Milestone 51: An understanding of the social-legal and ethical context of developments in bionics (end Year 2).

Milestone 52: An understanding of the impact of commodification on the development of bionics and the clinical applications of bionics (end early Year 3).

P5-2 "Bionic People"

Milestone 53: An understanding of the significance of bionics for self-identity and uses of the self: ethics and the self (end Year 3).

Milestone 54: Develop an integrated position on the development of bionics, human health and ethical relations (end Year 5).

Education milestones

Milestone 55: Establishment of ethics program and first cohort of staff and students trained (End Year 1).

The ethics program has been established and the first cohort of students have been trained through the conduction of two workshops held in 2006 at Wollongong and Monash. The Ethics and Regulation Workshops were two half-day events (at Monash University and at the University of Wollongong), supported through ACES and ARCNN for early career researchers and HDR candidates working in nanotechnology. The Workshops provided participants with an introduction to some emerging ethical and regulatory issues in nanoscience and nanotechnology; an opportunity to develop skills in identifying and articulating responses to ethical and regulatory issues through case studies; and an opportunity to meet, debate and hear the views of some key Australian researchers and practitioners in the areas of nanoethics and nanoregulation.

The workshops on ethics and regulation in nanotechnology were held in August 2006 at two venues, Wollongong and Monash. The events were hosted by ACES and partly sponsored by the ARC Nanotechnology Network.These two workshops were well-attended (approximately 35 participants at Wollongong and 18 at Monash) and well-received. Susan Dodds developed the case studies and facilitated the workshops. There were four invited speakers and support from Will Price (Wollongong) and Maria Forsyth (Monash) as well as other ACES staff.

Each invited speaker presented their overview of the key issues for regulators and ethicists as these technologies emerge. At Wollongong the presenters were Prof John Weckert (Information Technology, Charles Sturt University and ARC Key Centre for Applied Philosophy and Public Ethics); Ms Diana Bowman (Law, Monash University) and Dr Peter Binks (NanoVic). At Monash Dr Rob Sparrow (Philosophy and Bioethics, Monash University) replaced Prof Weckert; Diana Bowman and Peter Binks presented at both workshops.

Participants were encouraged to read the 2006 UNESCO Publication *The Ethics and Politics of Nanotechnology* prior to the workshops. At both workshops, participants were given the opportunity to work through some of the ethical and regulatory issues of nanotechnology through two cases. In the first, participants were asked to develop criteria for research assessors who were to set priorities in research funding based on the "national benefit" of nanotechnology research. This required participants to identify the different kinds of "goods" that nanoscience/ nanotechnology could generate, their relative importance for a society like Australia, the relative likelihood of different benefits being achieved in the foreseeable future and the significance of allocating public funding to different research areas. The second case asked participants to identify what for that group were considered to be the key factors of nanotechnologies that required some form of regulatory response; to explain why those factors were significant; and to explain what kind of regulatory structure would be appropriate for those concerns. All presenters offered commentary on the group discussion findings. It is anticipated that the workshops will be run again next year with the prospect of attracting good numbers of external delegates.

Milestone 56: Development of characterisation short courses and workshops (end Year 1).

The first in a series of characterisation workshops has been held in Wollongong during 2006. The theme for the two day workshop was carbon nanotubes (CNT) and the audience were internal members of ACES. The workshop feature both tutorial and hands-on sessions where delegates could see state of the art facilities for synthesis and characterisation of CNT. The feedback and lessons learnt form this workshop will be used to mount a revised format for the program which will be offered to external delegates in 2007. The format will also be used as a template for future events on characterisation techniques.

Milestone 57: Full Development of community outreach programs at Monash and Wollongong Science Centres (end Year 3).

Will be established during 2007.

Appendix II: ACES students

Name	Host Institution	Commenced	Title	Financial Arrangements
Liu Yong	IPRI/UoW	January 2004	Nanostructured electrodes based on carbon nanotubes.	UoW. ARC scholarship
Orawan Ngamna	IPRI/UoW	January 2004	Synthesis and characterisation of ICP nanoparticles.	UoW. ARC scholarship
Jenny Causley	IPRI/UoW	January 2004	Use of electrode nanostructures for fluid movement.	UoW scholarship/ ARC top up
Xiao Liu	IPRI/UoW	2005	Cell culturing on organic conductors	ARC Centre scholarship
Fatemeh Masdarolomoor	IPRI/UoW	2003	Nanostructured PMAS	Overseas scholarship
Salvador Larios	IPRI/UoW	2005	Hydrogel micro and nano actuators	IPRS
Vahid Mottaghitalab	IPRI/UoW	2003	Spinning polyaniline fibres	Overseas scholarship
Mehrdad Samani	IPRI/UoW	2004	Modelling of polypyrrole helix tube actuators	Iranian Government
Stephen John	UoW	2005	Conducting polymer based micro and nano manipulation systems	APA
Brianna Thompson	IPRI/UoW	2005	Cell culturing on conducting polymers	APA scholarship/ ARC top up
Yanzhe Wu	IPRI/UoW	2003	Conducting polymers and Cochlear implants	CRC scholarship
Javad Foroughi	IPRI/UoW	2006	Nanostructured fibres	ARC Centre scholarship
Bill Hawkins	UoW	2003	Methods for the Synthesis of Polyfunctionalized Fullerenes.	UoW/ARC
See How Ng	ISEM/UoW	July 2004	Nano-structured materials for electrode in Li-ion battery.	UoW
Min Sik Park	ISEM/UoW	September 2005	Thin film lithium-ion batteries	ISEM
Sau Yen Chew	ISEM/UoW	February 2006	Develop highly conductive nanocomposite electrolytes and electrodes for lithium batteries	ARC
Nolene Byrne	Monash	March 2003	The effect of composition on the ion dissociation in polyelectrolyte gels.	ARC
Sharyn Long	Monash	February 2002	Ionic conductivity in doped molecular plastic crystals.	ARC
Gary Annat	Monash	March 2004	Ionic Liquids for stable lithium cathode materials.	CSIRO Li Project funds
Tracey Markly	Monash	July 2005	Electrochemical and Surface characterisation of rare earth inhibited aluminium alloys	Monash
Youssof Shekibi	Monash	March 2005	Novel Plastic Crystal Electrolyte Materials	ARC & CSIRO Energy Technology top up.
Nickita Rajoo	Monash	March 2003	Development of Biosensors Based on Peptide Nucleic Acids.	ARC
Andrew Nattestad	Monash	February 2006	Dye Sensitised Tandem Solar Cells for Improved Conversion Efficiency	Monash
Stephen Zhang	Monash (undergrad)	December 2005	Mg alloy corrosion protection using IL treatments	ARC
Katarina Johansson	Monash	January 2005	New ionic liquids	Monash

Daniel Ho	Monash	March 2003	Efficacy and characterisation of Ce organophosphate inhibitors for AA2024-T3	Monash/DSTO
Aleksey Izgorodin	Monash	November 2006	Synthesis and characterisation of electroluminescent inorganic nanoparticles	ARC
Michael Ferguson	Monash (Undergrad)	Feb 2006	Synthesis and characterisation of novel electrodes for Dye Sensitised Tandem Solar Cells	ARC (maintenance)
Matthias Pauley	Monash (French intern)	October 2005	Surface characterisation of rare earth inhibitor treated metals	Monash
Vincent Bergout	Monash (French intern)	May 2006	IL treatment of reactive metal surfaces-	ARC
Franck Fougeron	Monash (French intern)	May 2006	Ionic liquid treatment of reactive metal surfaces - electrochemical and surface characterisation	ARC

Appendix III: Symposium invited speakers

Electromaterials Science Symposium Invited Speakers

Prof Graeme Clark (Bionic Ear Institute, Melbourne, Australia), "Taking the bionic ear from bench to bedside: Interfacing sound to the human consciousness".

Prof Ray Baughman (NanoTech Institute, University of Texas at Dallas, USA), "Multifunctional carbon nanotube yarns and textiles for fun and profit".

Prof Max Lu (Nanomaterials Centre, University of Queensland, Australia), "Composite membranes of polymer and inorganic colloidal particles with high proton conductivity and low methanol permeability".

Prof Siegmar Roth (Synthetic Nanostructures Group, Max Planck Institute for Solid State Research, Germany), "Experimental cross-checks on index-identified individual single-walled carbon nanotubes".

Prof Philippe Poulin (CNRS Bordeaux, France), "Phase behaviour of carbon nanotube suspensions".

Prof Geoffrey Spinks (ARC Centre of Excellence for Electromaterials Science, University of Wollongong, Australia), "Carbon nanotube reinforcement of conducting polymers and hydrogels for high strength actuators".

Prof Frank Walsh (Electrochemical Engineering Group, School of Engineering Sciences, University of Southampton, UK), "Protonated titanate nanotubes: synthesis, microscopy and electrochemistry".

Prof Danilo de Rossi (University of Pisa, Italy), "Electroactive polymer-based devices for e-textiles in biomedicine".

Prof Dermot Diamond (Adaptive Sensors Group, National Centre for Sensors Research, School of Chemical Sciences, Dublin City University, Ireland), "Adaptive surfaces on spiropyran molecular switches – building tailored features at the nanoscale".

Assoc Prof John Madden (Advanced Materials and Process Engineering Laboratory and the Department of Electrical & Computer Engineering, University of British Columbia, Canada), "Modeling transport in conducting polymer actuators and supercapacitors: the consequences and nanostructuring".

Prof David Officer (Nanomaterials Research Centre and the MacDiarmid Institute for Advanced Materials and Nanotechnology, Massey University, New Zealand), "Functional nanomaterials for energy conversion".

Prof Richard Kaner (Department of Chemistry and Biochemistry and California NanoSystems Institute, University of California, Los Angeles, USA), "Processable polyaniline nanofibres for flash welding, sensors and actuators".

Prof Douglas MacFarlane (ARC Centre for Electromaterials Science, School of Chemistry, Monash University, Australia), "Biocompatible ionic liquids and electrolytes".

Prof Maria Forsyth (ARC Centre for Electromaterials Science, School of Physics and Materials Engineering, Monash University, Australia), "Control of charge transport in solid materials: from electrochemical devices to corrosion mitigation".

Prof Simon de Leeuw (Department of Physical Chemistry and Molecular Thermodynamics, Delft University of Technology, The Netherlands), "Computer simulation of electrolytes and electrode materials".

Assoc Prof Justin Cooper-White (Tissue Engineering and Microfluidics Laboratory, Division of Chemical Engineering and the Australian Institute for Bioengineering and Nanotechnology, University of Queensland, Australia), "Smart scaffolds for muscle tissue engineering".

Prof Andrew B. Holmes (Bio21 Institute, University of Melbourne, Australia), "Organic electronic materials: next generation semiconductors".

Appendix IV: Full Centre Meeting (May 06)

ACES Full Centre Meeting
Monash Science Centre
10-11 MAY 2006

Attendees

Monash University
Prof Maria Forsyth
Prof Douglas MacFarlane
Prof Leone Spiccia
Dr Steven Pas
Dr Patrick Howlett
Dr Jenny Pringle
Dr Bjorn Winther-Jensen
Dr Peter Newman
Dr Gilles Gasser
Dr Katya Izgorodina
Dr Jiazeng Sun
Youssof Shekibi
Tracey Markley
Gary Annat
Andrew Nattestad
Nolene Byrne
Nicki (Rajoo)
Katarina Johansson
Stephen Zhang
Simon Thompson
Vijay Ranganathan
Kevin Fraser
Suzie Tan
David Menzies
Matthias Pauly
Vincent Bergeot
Franck Fougeron
Hongwei Han
Christopher Hutchinson
Pamela Dean

University of Wollongong
Prof Gordon Wallace
Assoc Prof Will Price
Dr Peter Innis
Dr Kerry Gilmore
Dr Binbin Xi
Dr Joselito Razal
Kaylene Atkinson
Andrew Minett
Brianna Thompson
Xiao Liu
Liu Yong
Yanzhe Wu
Sau Yen Chew
Jiazhao Wang

Massey University, New Zealand
Prof David Officer
Dr Klaudia Wagner
Dr Mark Waterland
Adam Swanson

Bionic Ear Institute
Dr Rachael Richardson
Dr Adrian Cameron

CSIRO
Dr Anita Hill

St Vincent's Hospital, Melbourne
Dr Robert Kapsa

Oral Presentations

Opening/Introduction – Professor Maria Forsyth

Dr Binbin Xi, University of Wollongong
Advances in Actuators

Dr Bjorn Winther Jensen, Monash University
Current Density in Highly Conducting Polymers

Dr Peter Newman, Monash University
Adventures in Nanotechnology: Preparation and Properties of Zinc Sulphide and Cadmium Selenide

Dr Gilles Gasser, Monash University
Towards Electrochemical Detection of Specific DNA/RNA Strands with Peptide Nucleic Acids bearing a Ferrocenyl Moiety

Dr Kerry Gilmore, University of Wollongong
CNT-SIBS Composites for Cell Culturing

Youssof Shekibi, Monash University
The Study of Plastic Crystals as Solid-State Electrolyte Materials

Dr Rachel Richardson, Bionic Ear Institute
Improving the Nerve-Electrode Interface of the Cochlear Implant

Liu Yong, University of Wollongong
Electrospinning Novel Composites

Yanzhe Wu, University of Wollongong
Controlling Fluid Movement

Dr Klaudia Wagner, Massey University, NZ
Investigations of Amine Functionalized Poly(terthiophene)s and their Modified Analogues

Brianna Thompson, University of Wollongong
Controlled Release of NT3

Tracey Markley, Monash University
Characterisation of New Rare Earth Organophosphates as Corrosion Inhibitors for AA2024-T3

Dr Joselito Razal, University of Wollongong
Spinning CNT Fibers

Gary Annat, Monash University
Binary Mixtures of Ionic Liquids

Andrew Nattestad, Monash University
Dye Sensitized Tandem Solar Cells for Improved Conversion Efficiency

Nolene Byrne, Monash University
An Understanding of the Effect of Zwitterion on the Lithium SEI in Ionic Liquid Electrolytes. An XPS and Solid State NMR Study

Dr Adrian Cameron, Bionic Ear Institute
Use of Conducting Polymers for Neural Regeneration

Dr Robert Kapsa, St Vincents Hospital, Melbourne

Posters

Dr Steven Pas, Monash University
Tailoring the Concentration and Connectivity of Defects in Plastic Crystals

Dr Patrick Howlett, Monash University
Control of Charge Transport at Reactive Metal Surfaces using Ionic Liquids

Dr Jenny Pringle, Monash University
Synthesis of Conducting Polymer Nanoparticles in an Ionic Liquid

Dr Jiazeng Sun
Gel Electrolytes based on Lithium Modified Silica Nano-particles

Stephen Zhang, Monash University
An Investigation of a Phosphinate-based Ionic Liquis for Corrosion Protection of Magnesium Alloy AZ31

Xiao Liu, University of Wollongong
Endothelial Cells on Active Surfaces

Sau Yen Chew, University of Wollongong
SnO_2 Polypyrrole Composite for Li Ion Batteries

Jiazhao Wang, University of Wollongong
Nanosize MoS_3 Particle Electrodes

Nicki (Rajoo), Monash University
Novel Ruthenium (III) Complexes Incorporating MonoCarboxylate Bipyridine Ligands

Katarina Johansson, Monash University
Volatile Ionic Liquids

Vijay Ranganathan
Kevin Fraser
Masahira (Yoshi) Fujita
Proton Conduction Mechanism in Zwitterionic Liquids

Kyoko Fujita
Ionic Liquids as Protein Solvents

Appendix V: Visitors to ACES in 2006

Visitors to IPRI venue

Date	Visitor	Affiliation	Purpose
5/1/06(1 month)	Prof Seon Jeong Kim	Hanyang University, Korea	Visiting scientist
5/1/06	Dr Rod Shepherd	DCU, Ireland	Meeting
10/1/06(3 months)	Lynn Dennany	DCU, Ireland	Visiting scientist
10/1/06(3 months)	Emmet O'Reilly	DCU, Ireland	Visiting scientist
11/1/06	Don Martin	UTS	Seminar
12/1/06	Greg Smith	SciVentures	IP Workshop
17/1/06(4 months)	Claire McMorrow	DCU, Ireland	Visiting scientist
23/1/06	Dr Attila Mozer	Osaka University, Japan	Seminar
24/1/06	Dr Peter Murphy	Uni. of South Australia	Meeting
31/1/06 (3 months)	Lorraine Nolan	DCU, Ireland	Visiting scientist
7/2/06 (1 month)	Prof. Dennis Tallman	NDSU, USA	Visiting scientist
7/2/06	Dr David Officer	Massey University, NZ	Meeting
10/2/06	Prof Jang Myoun Ko	Hanbat National University, Korea	Meeting
13/2/06 (10 days)	Prof Frank Walsh	University of Southampton, UK	Invited speaker for ACES Inaugural Electromaterials Science Symposium
13/2/06(2 weeks)	Dr Tan Truong	DSTO	Visiting scientist
13/2/06(10 days)	Prof Dermot Diamond	DCU, Ireland	Invited speaker for ACES Inaugural Electromaterials Science Symposium
13/2/06(5 days)	Dr John Madden	University of British Columbia, Canada	Invited speaker for ACES Inaugural Electromaterials Science Symposium
14/2/06	Dr Jan Weber	Boston Scientific, USA	Visiting scientist
14/2/06	Prof. Alan Bond	Monash University	Visiting scientist
20/2/06(2 weeks)	Neil Carolan	DCU, Ireland	Visiting scientist
20/2/06(3 months)	Junehwa Kim	Sunchon National University, South Korea	Visiting scientist
21/2/06	Dr Keld West	Riso National Laboratory, Denmark	Seminar
21/2/06	Aron Downie	Macquarie University	Meeting
21/2/06	Lucy Macnaught	Macquarie University	Meeting
24/2/06	Rolf Drewes	Ciba, Switzerland	Meeting
27/2/06(1 week)	Marc in het Panhuis	University of Hull, UK	Visiting scientist
28/2/06	Colin Raston	University of Western Australia	Seminar
2/3/06	Gerry Swiegers	CSIRO	Meeting
3/3/06	Peter Abolfathi	RNSH	Meeting
3/3/06	Dr Eric Amis	National Institute of Standards and Technology, USA	Meeting
9/3/06(3 months)	Dr Yingpit Pornputtkul		Visiting scientist
10/3/06	William Ducker	University of Melbourne	Meeting
10/3/06	J.-P. Pascault	CNRS, France	Seminar
14/3/06	Victor Luca	ANSTO, Menai	Seminar
15/3/06	Dr Peter Murphy	Uni. of South Australia	Meeting
16/3/06(3 days)	Dr David Officer	Massey University, NZ	Meeting
17/3/06	Claudiu Treaba	Cochlear Limited	Meeting

Appendix V: Visitors to ACES in 2006

20/3/06	Therese Carolan		PhD student
20/3/06(5 days)	Jenny Pringle	Monash University	Visiting scientist
22/3/06	Pinsuda Viravathana	Kasetsart University, Bangkok, Thailand	Visiting scientist
22/3/06	Gavin Collis	CSIRO	Meeting
22/3/06	Ian Dagley	CRC	Meeting
22/3/06	Gerry Wilson	CSIRO	Meeting
22/3/06	Dr Takahashi Ryuichi	CIBA, Japan	Meeting
24/3/06	Evan Evans	BlueScope Steel	Meeting
28/3/06(4 days)	Sukon Phanichphant	Chiang Mai University, Thailand	Visiting scientist
30/3/06	Robert Kapsa	St Vincent's Health	Meeting
30/3/06	Anita Quigley	St Vincent's Health	Meeting
5/4/06	Assoc Prof Laura Poole-Warren	UNSW	Seminar
7/4/06	Prof Chris Fell	NCRIS	Meeting
7/4/06	Dr Nigel Taylor		Special Discussion
10/4/06	Scott Callaghan	ThinkCentric	Meeting
10/4/06	Prof Peter Notten	Eindhoven University of Technology, Netherlands	Seminar
24/4/06(5 weeks)	Aoife Morrin	DCU, Ireland	Visiting scientist
28/4/06	Doug MacFarlane	Monash University	Meeting
28/4/06	Maria Forsyth	Monash University	Meeting
4/5/06	Dr Holly Shuman	Ceralink Inc., USA	Meeting
9/5/06	Dr Stefano Passerini	ENEA, Italy	Seminar
9/5/06	Members of the public		Public Lab Tour – Innovation Week
12/5/06	Dr David Officer	Massey University, NZ	Meeting
15/5/06	Scott Callaghan	ThinkCentric	Meeting
15/5/06	Ashton Bishop	ThinkCentric	Meeting
15/5/06	Gavin Larkin	ThinkCentric	Meeting
15/5/06	Warren Smith	Nanosonics Ltd	Meeting
18/5/06	Dr Don Martin	UTS	Meeting
18/5/06	Colin Hall	Univ. of South Australia	Meeting
18/5/06	Tracey Wright		Meeting
18/5/06	Rod Urquhart	CRC for Functional Communication Surfaces	Meeting
19/5/06	Dr Phillip Aitchison	CAP-XX	Meeting
23/5/06	Dr Mike Kuiper	VPAC	Meeting
23/5/06	Bill Humphries	CSIRO	Meeting
23/5/06	Ken Atkinson	CSIRO	Meeting
26/5/06	Barry Holcombe	CSIRO	Meeting
26/5/06	Bjorn Winther-Jensen	Monash University	Meeting
26/5/06	Noel Clark	CSIRO	Meeting
30/5/06(4 days)	Dr Greg Smith	SciVentures	Help us develop an IP strategy
30/5/06	Robert Kapsa	St Vincent's Health	Meeting
30/5/06	Prof Graeme Clark	Bionic Ear Institute	Meeting
2/6/06	Science Faculty Advisory Board	UoW	Tour
5/6/06(2 weeks)	Dr Tan Truong	DSTO	Visiting scientist

7/6/06	Dr Peter Murphy	Uni of South Australia	Meeting
22/6/06	Prof. Marcela Bilek	University of Sydney	Meeting
23/6/06	Doug MacFarlane	Monash University	Meeting
26/6/06	John Bartlett	ANSTO	Meeting
26/6/06	Gavin Collis	CSIRO	Meeting
6/7/06	Representatives	NAB and Standard & Poors	See and report back on how the Australian Government's money is being spent on us
13/7/06	Chinese Delegation	Chinese Universities, China	Research Management
14/7/06	Dr Andrew King	DTI Global Watch Service, UK	Meeting
21/7/06	Dr Peter Riley	BlueScope Steel	Meeting
21/7/06(1 week)	Park Jun-Ho	Hanbat National UniversitySouth KOREA	Visiting scientist
21/7/06	Dr Trevor Lewis	University of Tasmania	Meeting
26/7/06(1 month)	Su Ryon Shin	Hanyang University, Korea	Visiting scientist
26/7/06(1 month)	Ji Won Lee	Hanyang University, Korea	Visiting scientist
27/7/06	Scott Edwards	Schefenacker	Meeting
27/7/06	Dr Dag Wagner	Global Adv Eng	Meeting
3/8/06	Scott Edwards	Schefenacker	Meeting
3/8/06	Dr Peter Murphy	Uni. of South Australia	Meeting
3/8/06	Hans Griesser	Uni. of South Australia	Meeting
3/8/06	James Nicholson	Schefenacker	Meeting
8/8/06	Bjorn Winther-Jensen	Monash University	Meeting
8/8/06	Jenny Pringle	Monash University	Meeting
8/8/06	Julie & Josh Gin		Meeting
9/8/06	Dr David Officer	Massey University, NZ	Meeting
9/8/06	Dr Peter Riley	BlueScope Steel	Meeting
9/8/06	Dr David Christian	BlueScope Steel	Meeting
9/8/06	Dr Evan Evans	BlueScope Steel	Meeting
9/8/06	Dr Phil Barker	BlueScope Steel	Meeting
9/8/06	Dr David Buxton	BlueScope Steel	Meeting
9/8/06	Ken Jessop	BlueScope Steel	Meeting
9/8/06	Troy Lowe	BlueScope Steel	Meeting
11/8/06	Gerry Swiegers	CSIRO	Meeting
14/8/06	Greg Smith	SciVentures	Meeting
17/8/06	Russell Tait	Bionics Australia	Meeting
18/8/06	Anthony O'Mullane	Monash University	Seminar
23/8/06	Ian Dagley	CRC	CRC-P Project 3.1
23/8/06	Gavin Collis	CSIRO	CRC-P Project 3.1
23/8/06	Julia Krstina		CRC-P Project 3.1
23/8/06	Chris Harris		CRC-P Project 3.1
23/8/06	Mark Bown		CRC-P Project 3.1
23/8/06	Mei Gao		CRC-P Project 3.1
23/8/06	Jonathan Campbell		CRC-P Project 3.1
23/8/06	Gerry Triani		CRC-P Project 3.1
4/9/06(3 days)	Priya Subramanian	Monash University	CRC-FCS Project 2.08
5/9/06(3 months)	Zhiming Wang	Trinity College, Dublin	Visiting scientist
5/9/06(3 months)	Mark Steacy	Trinity College, Dublin	Visiting scientist

Appendix V: Visitors to ACES in 2006

8/9/06	Bjorn Winther-Jensen	Monash University	Meeting
8/9/06	Dr Noel Clark	CSIRO	Meeting
8/9/06	Nafty Vanderhoek	CSIRO	Meeting
18/9/06(2 weeks)	Dr Tan Truong	DSTO	Visiting scientist
21/9/06	Dr Peter Riley	BlueScope Steel	Meeting
21/9/06	Andy Holmes	University of Melbourne	Meeting
21/9/06	Robert Kapsa	St Vincent's Health	Meeting
21/9/06	Dr Phil Churchward	Bionic Technologies Australia	Meeting
22/9/06	Justin Cooper-White	University of Queensland	Meeting
26/9/06	Dr David Officer	Massey University, NZ	Meeting
26/9/06	David Salt	ANU	Meeting
27/9/06	Dr Ray Shaw	Rio Tinto	Linkage Meeting
27/9/06	Dr Richard John	Griffith University	Open Day
27/9/06	James Nicholson	Schefenacker	Open Day
27/9/06	Dr Peter Riley	BlueScope Steel	Open Day
27/9/06	Dr Anton Dominis	Figtree High School	Open Day
27/9/06	Claudiu Treaba	Cochlear Limited	Open Day
27/9/06	Edmond Capcelea	Cochlear	Open Day
3/10/06(2 months)	Dr Mahendra Shirsat	India	Visiting scientist
5/10/06(2 days)	Jenny Pringle	Monash University	Visiting scientist
12/10/06	Mats Bjorklund	Magipics	Meeting
13/10/06	Dr Paul Dastoor	University of Newcastle	Seminar
3/11/06	Andrew Battle	UTS	Seminar
7/11/06	Prof. Simon Ringer	University of Sydney	Seminar
7/11/06	Dr Zongwen Liu	University of Sydney	Meeting
7/11/06	Dr Kyle Ratinac	University of Sydney	Meeting
7/11/06	Dr Rongkun Zheng	University of Sydney	Meeting
8/11/06	Guangling Song	University of Queensland	Seminar
8/11/06	Greg Smith	SciVentures	Meeting
9/11/06	Rose Amal	UNSW	Seminar
9/11/06	Dr Dong Ho Sul	Hanbat National University	Meeting
9/11/06	Dr Name Kee-wan	Hanbat National University	Meeting
9/11/06	Dr Song Ha-young	Hanbat National University	Meeting
9/11/06	Mr Gang Hee-geun	Hanbat National University	Meeting
14/11/06	Udo Bach	Monash University	Seminar
14/11/06	Amy Halliday	Bionic Ear Institute	
15/11/06	Rahul Shastry	University of Canterbury, NZ	Seminar
16/11/06	Prof Graeme Clark	Bionic Ear Institute	Meeting
16/11/06	Dr David Officer	Massey University, NZ	Meeting
16/11/06	Robert Kapsa	St Vincent's Health	Meeting
17/11/06	Doug MacFarlane	Monash University	Meeting
17/11/06	Maria Forsyth	Monash University	Meeting
22/11/06	Dr David Rand	CSIRO	Seminar
22/11/06	Dr John Carras	CSIRO	Seminar
22/11/06	Dr Chris Fell	CSIRO	Seminar
22/11/06	Sten-Eric Lindquist	CSIRO	Seminar
5/12/06	Dr Emily Hilder	University of Tasmania	Meeting
8/12/06	Boyko Stoimenov	Bio-mimetic Control Research Center in Japan's RIKEN Institute	Seminar

Visitors to ISEM venue

Date	Visitor	Affiliation	Purpose
1/1/06-15/1/06	Prof J-H Ahn	Andong National University, Korea	Visiting scientist and seminar speaker
27/1/06-8/2/0611/11/06-30/11/06	Dr S. Zhong	Guangzhou Delong Energy Tech Ltd, China	Seminars
Feb/2006-Feb/2007	Prof C. Feng	Hubei University, China	Visiting scientist
10/April/2006	Prof P. Notten	Philips Research Lab, Netherlands	Visiting scientist and seminar speaker
28/4/06-8/5/06	Dr X.F. Gao	Lexcel battery Ltd, China	Seminar speaker
16/5/05-6/8/06	Dong-Yun Zhang	Shanghai Jiao Tong University, China	PhD student researcher
11/7/06-9/8/06	Prof J. Chen	Nankai University, China	Visiting scientist and seminar speaker
2/11/06-21/11/06	Dr K. Kim	Korea Electrotechnology Research Institute	Visiting scientist and seminar speaker

Appendix V: Visitors to ACES in 2006

Visitors to Monash venue

Date	Visitor	Affiliation	Purpose
9/2/06	Mr Tony Hughes	CMIT	Project
13/2/06	Prof Anders Hagfeldt	Royal Institute of Technology, Sweden	Seminar
22/2/06	Prof Richard Kaner	UCLA, USA	Seminar
15/3/06	Prof Gordon Wallace	IPRI, University of Wollongong	Executive Committee Meeting
15/3/06	Prof Graeme Clark	Bionic Ear Institute	Executive Committee Meeting
15/3/06	Prof David Officer	Massey University, New Zealand	Executive Committee Meeting
22/3/06	Mr Tony HughesMr. Bruce Hinton	CMIT (Tracey Markley)	Project
22/3/06	Mr Scott Wade	CRC-CIEAM	Project
4/4/06	Mr Ken Cheah	Solar Systems	Project
1/5/06-6/6/06	Mr Vincent Bergeot	Ecole Polytechnique de l'Universite de Nantes, France	Occupational Trainee
1/5/06-28/7/06	Mr Franck Fougeron	Ecole Polytechnique de l'Universite de Nantes, France	Occupational Trainee
5/5/06-31/7/06	Ms Rachna Agarwal	Indian Institute of Technology, India	Occupational Trainee
6/5/06-13/5/06	Dr Stefano Passerini	ENEA-IDROCOMB, Italy	Seminar
8/5/06	Prof Ken Seddon	Queens University, Ireland	Seminar
8/5/06	Prof Frank Endres	Clausthal University of Technology, Germany	Seminar
10/5/06	Prof Gordon Wallace Assoc Prof Will Price Dr Peter Innis Dr Kerry Gilmore Dr Binbin Xi Dr Joselito Razal Dr Andrew Minett Ms Kaylene Atkinson Brianna Thompson Xiao Lu Liu Yong Yanzhe WuSau Yen Chew Jiazhao Wang	IPRI, University of Wollongong	Workshop
10/5/06	Dr Anita Hill	CSIRO	Workshop
10/5/06	Prof David Officer Dr Klaudia Wagner Dr Mark Waterland Adam Swanson	Massey University, New Zealand	Workshop
10/5/06	Dr Rachael Richardon Dr Adrian Camerson	Bionic Ear Institute, Melbourne	Workshop
10/5/06	Dr Robert Kapsa	St.Vincents Hospital, Melbourne	Workshop

11-12/5/06	Frances Separovic Sau Yen Chew Dr Mark Waterland Kalyani Kathirgamanathan Ajit Pujari Prof Thomas Maschmeyer Prof Tony Masters Tennille Schultz Dr Klaudia Wagner EunHee Cha Jiazhao Wang Prof. Robin Rogers Dr Anna Pradi-Swab Prof Ken Seddon Prof Frank Endres Dr Patricia Hunt Dr Glenn Hefter Assoc Prof Will Price Dr Stefano Passerini Prof Geoff Stevens Dr Adam McCluskey Dr Ram Mohan John Nguyen Alexandru Let Noel Dunlop Scott Earnshaw Michelle Linley Nancy Francis	University of Melbourne University of Wollongong Massey University, NZ University of Auckland, NZ University of Sydney University of Sydney University of Sydney University of Sydney Massey University, NZ Korea Universityof Wollongong University of Alabama, USA Degussa AG, Germany Queens University, Ireland Clausthal University of Technology, Germany Imperial College, UK Murdoch University, WA University of Wollongong ENEA-IDROCOMB, Italy University of Melbourne University of Newcastle Illinois Wesleyan University, USA Cap-xx Cap-xx Orica Orica Orica Orica	Conference
24/5/06	Prof Gordon Wallace	IPRI, UOW	Executive Meeting
28/7/06	Dr Robert Kapsa	St. Vincents Hospital, Melbourne	Meeting
7/8/06	Mr Ken Cheah	Solar Systems	Project
28/7/06	Dr Robert Kapsa	St. Vincents Hospital, Melbourne	Meeting
18/8/06	Dr Mark Smith	University of Warwick, UK	
24/8/06	Dr Angus Gray-Weale	University of Sydney	Seminar
30/8/06	Prof Susan Dodds	UOW	Ethics Workshop
30/8/06	Dr Rob Sparrow	Bioethics, Monash University	Ethics Workshop
30/8/06	Mr Peter Binks	Nanovic	Ethics Workshop
30/8/06	Ms Diana Bowman	Law, Monash University	Ethics Workshop
19/9/2006	Mr Bruce Hinton		Meeting
3/10/2006	Mr Ken Cheah	Solar Systems	Project
13/10/2006	Mr Bruce Hinton		Meeting
24/10/2006	Dr Klaus Zicke	Bruker, Karlsruhe, Germany	NMR
27/10/2006	Mr Bruce Hinton		Meeting
30/10/2006	Dr Ali Mohammad Albishri Mr Saleh Dr Mohammad A. Al-Ohali	Saudi Arabian Cultural Attache Finance Manager, Saudi Arabian Embassy Dean, Graduate School, King Fahd University of Petroleum & Minerals	Saudi Arabian Visiting Delegation
1/12/2006	Dr Allison Davenport	Birmingham, UK	Seminar

Appendix VI: Invitations overseas in 2006

Invitations to visit leading international laboratories during 2006

Date	Name	Affiliation	Laboratory visited
27 Apr 2006	Prof Yibing Cheng	Monash	Institute of Physics, Chinese Academy of Sciences, China
April-May 2006	Dr Udo Bach	Monash	Dr Paul Alivisatos research group and laboratories, at UC Berkeley, USA
7-14 May 2006	Dr Guo Xiu Wang	ISEM, UoW	FE-SEM Lab, Andong National UniversityNanopowder Materials Group, Materials Technology Department, Korean Institute of Materials and Machinery (KIMM)
May 2006	Prof Graeme Clark	BEI/SVHM	Karolinska Institute, Stockholm
1-30 June 2006	Prof. L.Kane-Maguire	IPRI/Chemistry, UoW	Prof. E. Nordlander, Chemistry Dept, Lund University, Sweden LKM obtained a Wenner-Gren Foundation Award to support this visit
7-8 Jun 2006	Prof Maria Forsyth	Monash	Dr Mark Smith, University of Warwick laboratories, UK
12-15 June 2006	Prof Gordon Wallace and Dr Byung Chul Kim	IPRI, UoW	Prof. Seon Jeong Kim's group, Hanyang University, Korea.Prof Jang Myun Ko, Hanbat National University, Korea.Professor Gyou Jin Cho and Professor Jae Ki Kim President of Sunchon National University, Korea.
19-23 Jun 2006	Dr Steven Pas	Monash	Dr Ryoichi Suzuki, of the Advanced Defect-Characterization Research Group, Research Institute of Instrumentation Frontier, National Institute of Advanced Industrial Science and Technology (AIST), in Tsukuba, Japan
2 Jul 2006.	Prof Yibing Cheng	Monash	Prof Anders Hagfeldt and the Royal Institute of Technology, Stockholm, Sweden
5 July 2006	Prof Geoff Spinks	IPRI, UoW	VTT, Tampere Finland
11 Jul -18 Sept 2006	Dr Udo Bach	Monash	Prof Michael Graetzel and group at EPF, Lausanne, Switzerland
21-22 Jul 2006	Prof Maria Forsyth	Monash	Prof Austin Angell and group, and their laboratories, at University of Arizona, USA
23 Oct 2006-20 Apr 2007	See How Ng as a Guest Scientist	ISEM, UoW	Electrochemistry Laboratory, Paul Scherrer Institute (PSI), Switzerland
November 2006	Dr Steven Pas	Monash	Dr Ryoichi Suzuki of the Advanced Defect-Characterization Research Group, Research Institute of Instrumentation Frontier, National Institute of Advanced Industrial Science and Technology (AIST), in Tsukuba, Japan
11-12 Dec 2006	Prof Geoff Spinks	IPRI, UoW	Department of Biomedical Engineering, Hanyang University, Seoul, Sth Korea
Dec 2006	Prof Gordon Wallace and Dr Jun Chen	IPRI, UoW	Hangzhou University of Technology, Shanghai Jiao Tong University, and Shanghai Shen Li High-tech Co Ltd., China
Dec 2006	Dr Dan Li	IPRI, UoW	Nanjing University of Science and Technology, China

Appendix VII: Speaking invitations in 2006

Invitations to address conferences etc during 2006

Date	Speaker	Affiliation	Type of presentation	Title of presentation	Name of conference etc
Feb 2006	Prof Graeme Clark	BEI/SVHM	Plenary speaker	Taking the Bionic ear from bench to bedside: interfacing sound to the human consciousness	Inaugural Electromaterials Science Symposium
Mar 2006	Dr Andrew Minett	IPRI	Poster	Novel Route to (Bio)-Polymer Nanotube Composites',	International Winterschool on Electronic Properties of Molecular Nanostructures, 4-11th March, 2006, Kirchberg, Austria.
17-19 Apr 2006	Prof Gordon Wallace	IPRI	Invited speaker	Wearable Energy Conversion and Storage Systems: Novel Fibres and New Approaches	Materials Research Society 2006 Spring Meeting in San Francisco, USA
Apr 2006	Prof Doug MacFarlane	Monash	Invited speaker	Nano-crystallized Glasses for X-Ray Scintillation Applications	15th International Symposium on Non-oxide Glasses, Bangalore, India
12 May 2006	Prof Graeme Clark	BEI/SVHM	Prominent speaker	Cochlear Implants, from bench to bedside, the multiple-channel Cochlear Implant – the sensory interface between the world of sound and human consciousness – the Melbourne experience	37th Nobel Mini-symposium: frontiers in Medicine, Karolinska Institutet, Stockholm, Sweden.
12 May 2006	Prof Graeme Clark	BEI/SVHM	Keynote speaker	Cochlear Implants of the future: Advances in interfacing sound to the central nervous system	Hudinge Hospital, Stockholm
May 2006	A/Prof Paul Keller	UoW	Speaker	Towards Functional Nanomaterials: Investigations into the Multifunctionalisation of Fullerenyl Amino Acids	210th meeting of The Electrochemical Society (ECS): Denver
12-16 June 2006	Prof Maria Forsyth, Dr Jiazeng Sun	Monash	Invited speaker	"Gel electrolytes based on lithium modified silica nano-particles"	10th Asian Conference on Solid State Ionics (ACSSI-10), Kandy, Sri Lanka
June 2006	Prof Graeme Clark	BEI/SVHM	Keynote speaker	Lambie-Dew Oration and occasional address Graduation Ceremony	The University of Sydney
28-30 June 2006	Prof Hua Kun Liu	ISEM	Invited speaker	Nanocomposite materials for use in lithium rechargeable batteries	7th China International Battery Technical Conference, Beijing, China
July 3 2006	Prof Graeme Clark	BEI/SVHM	Plenary Lecture	The Cochlear Implant – the Biomedical Challenges	Bosch InstituteAnnual Scientific Meeting, The University of Sydney
9-12July 2006	Prof Hua Kun Liu	ISEM	Plenary speaker	The impact of Nanomaterials on lithium rechargeable batteries	6th International symposium on new materials for electrochemical systems, Montreal, Canada

16-21 July 2006	Prof Maria Forsyth	Monash	Invited discussion leader, and poster presentation	Discussion: "Metal-oxide-polymer interfaces, coatings and corrosion inhibition"; Poster: "New rare earth organophosphates for corrosion inhibition of AA2024-T3".	Gordon Research Conference on Corrosion-Aqueous, at Colby-Sawyer College, New London, New Hampshire, USA
July 2006	Prof Graeme Clark	BEI/SVHM	Keynote speaker	Cochlear Implants	International Christian Medical and Dental Congress
July 2006	Dr Andrew Minett	IPRI	SpeakerPoster	Carbon Nanotube Platforms for New BiomaterialsDecoration of carbon nanotubes with biological entities for electronic device applications	2006 International Conference on Nanoscience and Nanotechnology, 3-7th July, Brisbane Australia
Aug 2006	Prof Graeme Clark	BEI/SVHM	Address on the award of the Ian Wark medal		Australian Academy of Science
1st Sept 2006	Prof Graeme Clark	BEI/SVHM	Keynote Speaker	Biomedical Research Management Symposium	The University of Melbourne
10-14 Sept 2006	Prof Maria Forsyth	Monash	Invited speaker	"Transport properties of ionic liquids - origins in liquid structure", and "Lithium ion transport in polymer gel electrolyte membranes based on ionic liquids". Prof Forsyth also invited to chair a session.	American Chemical Society (ACS), Physical Chemistry Ionic Liquids Symposium, San Francisco, California, USA
10-14 Sept 2006	Prof Doug MacFarlane	Monash	Invited speaker	Dielectric Relaxation in Ionic Liquids Signatures of Dynamic Liquid Structure	American Chemical Society (ACS), National Meeting, San Francisco, California, USA
Sept 2006	Prof Gordon Wallace	IPRI	Plenary speaker	Nanostructured (Organic) Electrodes: New Bionic Interfaces"	World Congress on Medical Physics and Biomedical Engineering, Seoul, Korea.
Sept 2006	Prof Doug MacFarlane	Monash	Invited speaker	Electrochemistry in Ionic Liquids	EUCHEM Symposium on Ionic Liquids and Molten Salts, Tunisia
11Nov 2006	Prof Graeme Clark	BEI/SVHM	Guest of Honour/Speaker	"Hearing through nanobionics, electrophonics and mechatronics"	Bionics & Regeneration of the Ear
2006	Geoff Spinks	IPRI	Invited Speaker	Nanostructured polymers for biomimetic muscles	International Conference on Nano-Molecular Electronics, Kobe Japan

Appendix VIII: Media coverage in 2006

Media coverage for ACES in 2006

Date	Medium	Source	Description	Impact	Journalist
17/02/2006	Radio	ABC Illawarra	Gordon Wallace, the head of a new UOW research centre says the coming together of talented scientists will help the centre achive great results.	Positive	Paul Devenport
20/02/2006	Print	Australian Financial Review	Business wants innovation from research, such as that from UOW's Gordon Wallace and Peter Hoj.	Positive	Phil Clark
March 2006	Print	FEAST Focus Newsletter	UOW academic Dr Andrew Minett who works in the Intelligent Polymer Research Institute was highlighted in the Portrait of a Researcher section of the monthly newsletter of Forum on European Australian Science and Technology (FEAST).	Positive	Jean-Francois Desvignes-Hicks
31/03/2006	UOW home-page	UOW News Release	UOW News release reporting the installation of the new Atomate Chemical Vapour Deposition system installed in March in the Intelligent Polymer Research Institute laboratories.	Positive	media@uow.edu.au
4/04/2006	Print	Illawarra Mercury	UOW professor Gordon Wallace study of 'smart' materials and the newly installed carbon naotube facility have potential to save energy crisis.	Positive	
8/05/2006	Print	Illawarra Mercury	Professor Gordon Wallace and his team to showcase research into electromaterials sciences and nanotechnology.	Positive	
9/05/2006	Radio	ABC Illawarra	The intelligent Polymers Research Unit at UOW will be conducting a tour this afternoon as part of the Illawarra Innovation Showcase.	Positive	
11/05/2006	Television	WIN TV	UOW's first Australian Research Council Federation Fellowship awarded to Professor Gordon Wallace.	Positive	
11/05/2006	Television	WIN TV	Professor Gordon Wallace has received the UOW's first Australian Research Council Federation Fellowship.	Positive	
12/05/2006	Print	Illawarra Mercury	UOW professor Gordon Wallace the first UOW academic to be awarded an Australian Research Council Federation Fellowship.	Positive	Louise Turk
12/05/2006	Radio	ABC Illawarra	Professor Gordon Wallace says his research grant is aimed at advances in nanotechnology and in bridging the gap between conventional electronics and biology.	Positive	
12/05/2006	Radio	ABC Illawarra	Professor Gordon Wallace is awarded Australian Research Council Federation Fellowship.	Positive	
12/05/2006	Radio	ABC Illawarra	Report on UOW Intelligent Polymers Research Institute and their research.	Positive	
12/05/2006	Radio	ABC Illawarra	Report on UOW Intelligent Polymers Research Institute, including PhD student Brianna Thompson who says one area of research is cochlear implants.	Positive	

15/05/2006	Print	Financial Review	Gordon Wallace, UOW, hopes to use his $1.5 million to revolutionise medical science and create new bionic materials.	Positive	
15/05/2006	Magazine	Electronic News	UOW Intelligent Polymer Research Institute has installed a machine that will allow researchers to design and produce carbon nanotubes.	Positive	
27/05/2006	Print	Sydney Morning Herald My Career	Professor Gordon Wallace talks of his triumph with 'intelligent' polymers.	Positive	
3/06/2006	Magazine	Australian Life Scientist	Prof Gordon Wallace receives Life Science Federation Fellowship.	Positive	
20/06/2006	Web	www.azomano.com	The Intelligent Polymer Research Institute, which includes UOW, has internationally recognised expertise.	Positive	
14/07/2006	Print	Illawarra Mercury	Feature article on Prof. Spinks' research relating to artificial muscles	Positive	Self
July 2006	Print	Cosmos Magazine	Article written for "The first person ….series" – for major scientific magazine	Positive	
14/08/2006	Television	WIN TV	UOW's Intelligent Polymer Research Institute is to get a boost with five international scientists to join the team this year.	Positive	
Aug 2006	Radio	Radio National	Interview on program "The Conversation"	Positive	
Aug 2006	Television	Channel 10	"Where are they now" invited as guest along with recipients of bionic ear, Sophie Li and Rod Saunders	Positive	
29/08/2006	Print	The Age	Wise professor knows what's good for a campus town of innovation	Positive	Beverley Head
2/09/2006	Print	Sydney Morning Herald	UOW researchers in the Intelligent Polymer Research Institute are at the cutting edge of a new and rapidly expanding arm of nanotechnology.	Positive	Amy DeLore
7/09/2006	Print	Australian	UOW Prof Gordon Wallace is a recipient of a Federation Fellowship.	Positive	Derek Parker
7/09/2006	Print	Australian	Fellowship reverses brain drain	Positive	Derek Parker
9/10/2006	Print	The Australian	Bionic ear inventor Prof Graeme Clark is collaborating with UOW's Prof Gordon Wallace to find a way to deliver nerve growth factors.	Positive	Amy Byrne
Oct 2006	Print	Wealth Creator Magazine	Interview for article in magazine	Positive	
Oct 2006	Radio	ABC Canberra	Interview - Then, Now…Imagine' report for Research Australia "Thank You" Day	Positive	
31/10/2006	print	Bulletin	Spinal frontier – high tech plastics and nanomaterials	Positive	Joshua Gliddon
Nov 2006	Television	Channel 10	Mornings With David & Kim interview with Alan Schauder and his son Mikey	Positive	
8/12/2006	Print	Herald Sun	University of Melbourne announcement of normal language skills for young children with Cochlear implants	Positive	Kate Jones, medical reporter
12/12/2006	Print	Cosmos	Hearing is believing story	Positive	
16/12/2006	Print	Illawarra Mercury (Weekender)	Prof Gordon Wallace is the first Wollongong academic to be awarded an Australian Research Council Federation Fellowship.	Positive	

Appendix IX: ACES staff

ACES staff in 2006

Member	Role	Affiliation
Prof G.G. Wallace	Executive Director and Program 1 Leader	University of Wollongong
Prof. M. Forsyth	Associate Director	Monash University
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 Leader	Bionic Ear Institute
Prof S. Dodds	Program 5 Leader	University of Wollongong
Prof W.E. Price	Education Director	University of Wollongong
A/Prof C.O. Too	Chief Operating Officer	University of Wollongong
Prof L.A.P. Kane-Maguire	Chief Investigator	University of Wollongong
Prof D.L. Officer	Partner Investigator	Massey University
Prof H.K. Liu	Chief Investigator	University of Wollongong
A/Prof P. Keller	Chief Investigator	University of Wollongong
Prof H. Brown	Chief Investigator	University of Wollongong
Dr P. Innis	Chief Investigator	University of Wollongong
Dr A. Minett	Chief Investigator	University of Wollongong
Dr G. Alici	Chief Investigator	University of Wollongong
Prof L. Spiccia	Chief Investigator	Monash University
Prof Y-B. Cheng	Chief Investigator	Monash University
Dr R. Kapsa	Partner Investigator	St Vincent's Health
Ms K. Atkinson	Business Development Officer	University of Wollongong
Dr C. Lynam	Research Fellow	University of Wollongong
Dr S. Moulton	Research Fellow	University of Wollongong
Dr Dan Li	QEII Fellow	University of Wollongong
Dr S. Ashraf	Research Fellow	University of Wollongong
Dr G. Wang	Research Fellow	University of Wollongong
Dr Jenny Pringle	ARC Fellow	Monash University
Dr Josefina Adebahr	ARC Fellow	Monash University
Dr Jiazeng Sun	Research Fellow	Monash University
Dr Peter Newman	Research Fellow	Monash University
Dr Masahiro Y. Fujita	Research Fellow	Monash University
Dr Kyoko Fujita	Research Fellow	Monash University
Dr Gilles Gasser	Research Fellow	Monash University
Dr Patrick Howlett	Research Fellow	Monash University
Dr Udo Bach	ARC Fellow	Monash University
Dr Steve Pas	ARC Fellow	Monash University
Dr Bjorn Winther-Jensen	Research Fellow	Monash University
Dr Katya Izgorodina	Research Fellow	Monash University
Dr David Menzies	Research Fellow	Monash University
Ms. Siu Wai	Research Fellow	University of Wollongong
Dr. Binbin Xi	Research Fellow	University of Wollongong
Dr M. Imisides	Research Fellow	University of Wollongong
Dr G. Tsekouras	Research Fellow	University of Wollongong
Dr C. Wang	Research Fellow	University of Wollongong
Dr J. Wu	Research Fellow	University of Wollongong

Dr Adrian Cameron	Senior Research Fellow	Bionic Ear Institute
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
Prof J-Y. Lee	Associate Investigator	Korean Institute of Metals and Materials
Assist Prof J. Madden	Associate Investigator	University of British Columbia
Dr D. Paganin	Associate Investigator	Monash University
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 J. Wang	Associate Investigator	University of Wollongong

Appendix X: ACES publications in 2006

ACES publications in 2006

Refereed journal papers (IF = Impact Factor)

1. Synthesis of Chiral Polyaniline Films via Chemical Vapor Phase Polymerization. Chen, J., Winther-Jensen, B., Pornputtkul, Y., West, K., Kane-Maguire, L.A.P., Wallace, G.G. *Electrochemical and Solid-State Letters* 2006, 9 (1), C9-C11. **IF = 1.970**

2. Surprising shrinkage of expanding gels under an external load. Kim, S.J., Spinks, G.M., Prosser, S., Whitten, P.G., Kim, S.I., Wallace, G.G. *Nature Materials* 2006, 5, 48-51. **IF = 15.941**

3. Electrosynthesis of novel photochemically active inherently conducting polymers using an ionic liquid electrolyte. Murray, P.S., Ralph, S.F., Too, C.O., Wallace, G.G. *Electrochimica Acta* 2006, 51, 2471-2476. **IF = 2.453**

4. Fast Carbon Nanotube Charging and Actuation. Madden, J.D.W., Barisci, J.N., Anquetil, P.A., Spinks, G.M., Hunter, I.W., Wallace, G.G. *Advanced Materials* 2006, 18, 870-873. **IF = 9.107**

5. Carbon Nanotube Reinforced Polyaniline Fibres for High Strength Artificial Muscles. Spinks, G.M., Mottaghitalab, V., Bahrami-Samani, M., Whitten, P.G., Wallace, G.G. *Advanced Materials* 2006, 18, 637-640. **IF = 9.107**

6. Mechanical properties of chitosan/CNT microfibers obtained with improved dispersion. Spinks, G.M., Shin, S.R., Whitten, P.G., Kim, S.I., Kim, S.J., Wallace, G.G. *Sensors and Actuators* B 2006, 115, 678-684. **IF = 2.646**

7. A Simple Means to Immobilize Enzyme into Conducting Polymers via Entrapment. Chen, J., Winther-Jensen, B., Lynam, C., Ngamna, O., Moulton, S., Zhang, W., Wallace, G.G. *Electrochemical and Solid-State Letters* 2006, 9 (7), H68-H70. **IF = 1.970**

8. Functionalized polythiophene-coated textile: A new anode material for a flexible battery. Wang, C.Y., Ballantyne, A.M., Hall, S.B., Too, C.O., Officer, D.L., Wallace, G.G. *Journal of Power Sources* 2006, 156, 610-614. **IF = 2.77**

9. The development and characterisation of polyaniline-single walled carbon nanotube composite fibres using 2-acrylamido-2 methyl-1-propane sulfonic acid (AMPSA) through one step wet spinning process. Mottaghitalab, V., Spinks, G.M., Wallace, G.G. *Polymer* 2006, 47, 4996-5002. **IF = 2.849**

10. Electroless recovery of silver by inherently conducting polymer powders, membranes and composite materials. Dimeska, R., Murray, P.S., Ralph, S.F., Wallace, G.G. *Polymer* 2006, 47, 4520-4530. **IF = 2.849**

11. Polyaniline fibres containing single walled carbon nanotubes: Enhanced performance artificial muscles. Mottaghitalab, V., Xi, B., Spinks, G.M., Wallace, G.G. *Synthetic Metals* 2006, 156, 796-803. **IF = 1.32**

12. Conducting Polymer Nanoparticles Synthesized in an Ionic Liquid by Chemical Polymerisation. Pringle, J.M., Ngamna, O., Chen, J., Forsyth, M., MacFarlane, D.R., Wallace, G.G. *Synthetic Metals* 2006, 156, 979-983. **IF = 1.32**

13. Fast trilayer polypyrrole bending actuators for high speed applications. Wu, Y., Alici, G., Spinks, G.M., Wallace, G.G. *Synthetic Metals* 2006, 156, 1017-1022. **IF = 1.32**

14. Lithium-Polymer battery based on polybithiophene as cathode material. Chen, J., Wang, J., Wang, C., Too, C.O., Wallace, G.G. *Journal of Power Sources* 2006, 159, 708-711. **IF = 2.77**

15. Poly(3-methylthiophene) electrochemical actuators showing increased strain and work per cycle at higher operating stresses. Xi, B., Truong, V.-T., Whitten, P., Ding, J., Spinks, G.M., Wallace, G.G. *Polymer* 2006, 47, 7720-7725. **IF = 2.849**

16. Highly-flexible fibre battery incorporating polypyrole cathode and carbon nanotubes anode. Wang, J., Wang, C.Y., Too, C.O., Wallace, G.G. *Journal of Power Sources* 2006, 161, 1458-1462. **IF = 2.77**

17. Induction of chirality into a fully sulfonated poly(methoxyaniline) via acid-base interactions with chiral amines. Strounina, E.V., Kane-Maguire, L.A.P., Wallace, G.G. *Polymer* 2006, 47, 8088-8094. **IF = 2.849**

18. Swelling Behavior of Chitosan Hydrogel in Ionic Liquid-Water Binary Systems. Spinks, G.M., Lee, C.K., Kim, S.I., Kim, S.J., Wallace, G.G. *Langmuir* 2006, 22, 9375-9379. **IF = 3.705**

19. Nanocomposites of Polyaniline/Poly(2-methoxyaniline-5-sulfonic acid). Masdarolomoor, F., Innis, P.C., Ashraf, S., Kaner, R.B., Wallace, G.G. *Macromolecular Rapid Communications* 2006, 27, 1995-2000. **IF = 3.126**

20. Optimising the incorporation and release of a neurotrophic factor using conducting polypyrrole. Thompson, B.C., Moulton, S.E., Ding, J., Richardson, R., Cameron, A., O'Leary, S., Clark, G.M., Wallace, G.G. *Journal of Controlled Release* 2006, 116, 285-294. **IF = 3.696**

21. The multi-channel cochlear implant the interface between sound and the central nervous system for hearing, speech and language in deaf people. Clark, G.M. *Philos T Roy Soc B*, 2006, 361, 791-810. **IF = 4.997**

Appendix X: ACES publications in 2006

22. A methodology towards geometry optimization of high performance polypyrrole (PPy) actuators. Alici, G., Metz, P., Spinks, G.M. *Smart Materials & Structures* 2006, 15, 243-252. **IF=1.67**

23. Design, fabrication and testing of piezoelectric polymer PVDF microactuators. Fu, Y., Harvey, E.C., Ghantasala, M.K., Spinks, G.M. *Smart Materials & Structures* 2006, 15, S141-S146. **IF=1.67**

24. Nanomaterials for Lithium-Ion Rechargeable Batteries. Liu, H.K., Wang, G.X., Guo, Z.P. Wang, J.Z. and Konstantinov, K. J. *Nanosci. Nanotech*., 2006, l(6), 1–15. **IF = 1.932**

25. Highly reversible lithium storage in spheroidal carbon-coated silicon nanocomposites as anodes for lithium-ion batteries. Ng, S.H., Wang, J., Wexler, D., Konstantinov, K., Guo, Z.P., Liu, H.K. *Angewandte Chemie International Edition*, 2006, 45, 6896-6899. **IF = 9.596**

26. Spray pyrolyzed PbO-carbon nanocomposites as anode for lithium-ion batteries. Ng, S.H., Wang, J. Konstantinov, K. Wexler, D. Chen, J. and Liu, H.K. *J. Electrochem. Soc.*, 2006, 153 (4), A787-A793. **IF = 2.19**

27. Electrochemical properties of Si thin film prepared by pulsed laser deposition for lithium ion micro-batteries. Park, M.S., Wang, G.X., Liu, H.K., Dou, S.X. *Electrochimica Acta*, 2006, 51, 5246-5249. **IF = 2.453**

28. Conducting Poly(aniline) Nanotubes and Nanofibers: Controlled Synthesis and Application in Lithium/Poly(aniline) Rechargeable Batteries. Cheng, F., Tang, W., Li, C. Chen, J., Liu, H.K., Shen, P. and Dou, S.X. **Chem. Eur. J.** 2006, 12, 3082 – 3088. **IF = 4.907**

29. Electrochemical Performance of Co_3O4–C Composite Anode Materials. Needham, S.A., Wang, G.X., Konstantinov, K., Tournayre, Y., Lao, Z. and Liu,H.K. *Electrochemical and Solid-State Letters*, 2006, 9(7), A315-A319. **IF = 1.97**

30. Electro-Oxidation of Ethanol on Pt-WO_3/C Electrocatalyst. Zhang, D.Y., Ma, Z.F., Wang, G., Konstantinov, K., Yuan, X. and Liu, H.K. *Electrochemical and Solid-State Letters*, 2006, 9(9), A423-A426. **IF = 1.97**

31. Synthesis and Characterization of $LiFePO_4$ and $LiTi_{0.01}Fe_{0.99}PO_4$ Cathode Materials. Wang, G.X., Bewlay, S., Needham, S.A., Liu, H.K., Liu, R.S., Drozd, V.A., Lee, J.-F. and Chen, J.M. *J. Electrochem. Soc.*, 2006, 153(1), A25-A31. **IF = 2.19**

32. Nickel Oxide Nanotubes: Synthesis and Electrochemical Performance for Use in Lithium Ion Batteries. Needham, S.A., Wang, G.X., Liu, H.K. and Yang, L. *J. Nanosci. Nanotech.*, 2006, 6, 77-81. **IF = 1.932**

33. A new rapid synthesis technique for electrochemically active materials used in energy storage applications. Needham, S.A., Calka, A., Wang, G.X., Mosbah, A., Liu. H.K. *Electrochem. Comm.*, 2006, 8(3), 434-8. **IF = 3.388**

34. Nanostructured PbO materials obtained in situ by spray solution technique for energy saving applications. Konstantinov, K., Ng, S.H., Wang, J.Z., Wang, G.X., Wexler, D., Liu, H.K. *J. Power Sources*, 2006, 159, 241-244. **IF = 2.770**.

35. Spherical clusters of NiO nanoshafts for lithium-ion battery anodes. Yuan, L., Guo, Z.P., Konstantinov, K., Munroe, P., Liu, H.K. Electrochem. *Solid-State Lett*., 2006, 9(11), A524-A528. **IF = 1.97** (*selected for the Sept 25 2006 issue of Virtual Journal of Nanoscale Science & nanotechnology).

36. An Ionic Liquid Surface Treatment for Corrosion Protection of Magnesium Alloy AZ31. Forsyth, M., Howlett, P.C., Tan, S.K., MacFarlane, D.R. and Birbilis, N.R. *Electrochemical and Solid-State Letters*, 2006, 9(11), B52. **IF = 1.970**

37. Exploring Corrosion Protection of Mg via Ionic Liquid Pretreatment. Birbilis, N., Howlett, P.C., MacFarlane, D.R. and Forsyth, M. *Surface & Coatings Technology* 2006, 201(2007), 4496-4504. **IF = 1.646**

38. Electrochemistry at Negative Potentials in Bis(trifluoromethanesulfonyl)amide Ionic Liquids. Howlett, P.C., Izgorodina, E.I., Forsyth, M. and MacFarlane, D.R. *Zeitschrift fur Physikalische Chemie*, 2006, 220, 1483-1498. **IF = 1.161**

39. Unexpected Improvement in Stability and Utility of Cytochrome c by Solution in Biocompatible Ionic Liquids. Fujita, K., Forsyth, M., MacFarlane, D.R., Reid, R.W. and Elliott, G.D. *Wiley InterScience, Biotechnology and Bioengineering* 2006, 94, No. 6, 1209-1213. **IF = 2.483**

40. Cerium Dibutylphosphate as a Corrosion Inhibitor for AA2024-T3 Aluminium Alloys. Ho, D., Brack, N., Scully, J., Markley, T., Forsyth, M. and Hinton, B. *Journal of the Electrochemical Society* 2006, 153(9), B939-B401. **IF = 2.190**

41. Broadband Dielectric Response of the Ionic Liquid N-Methyl-N-Ethylpyrrolidinium Dicyanamide. Schroedle, S., Annat, G., MacFarlane, D.R., Forsyth, M., Buchner, R. and Hefter, G. *Chemical Communications* (Cambridge, United Kingdom) 2006, 16, 1748-1750. **IF = 4.426**

42. Developing Fast Ion Conductors from Nanostructured Polymers. Forsyth, M., Adebahr, J., Byrne, N. and MacFarlane, D. *Nanostructure Control of Materials* 2006, 97-114. **IF = N/A**

43. Dye-Sensitized Nanocrystalline Solar Cells Incorporating Ethylmethylimidazolium-Based Ionic Liquid Electrolytes. Dai, Q., Menzies, D.B., MacFarlane, D.R., Batten, S.R., Forsyth, S., Spiccia, L., Cheng, Y-B. and Forsyth, M. *Comptes Rendus Chimie* 2006, 9(5-6), 617-621. **IF = 1.577**

44. Lewis Base Ionic Liquids. MacFarlane, D.R., Pringle, J.M., Johansson, K.M., Forsyth, S.A. and Forsyth, M. Chemical Communications (Cambridge, U.K.), *The Royal Society of Chemistry* 2006, 18, 1905-1917. **IF = 4.426**

45. The "Filler-Effect" in Organic Ionic Plastic Crystals: Enhanced Conductivity by the Addition of Nano-sized TiO_2. Adebahr, J., Ciccosillo, N., Shekibi, Y., MacFarlane, D.R., Hill, A.J. and Forsyth, M. *Solid State Ionics* 2006, 177(9-10), 827-831. **IF = 1.571**

46. Zwitterion Effect in Polyelectrolyte Gels Based on Lithium Methacrylate-N,N-Dimethyl Acrylamide Copolymer. Sun, J., MacFarlane, D.R., Byrne, N. and Forsyth, M. *Electrochimica Acta* 2006, 51(19), 4033-4038. **IF = 2.453**

47. A New Lewis-Base Ionic Liquid Comprising a Mono-Charged Diamine Structure: A Highly Stable Electrolyte for Lithium Electrochemistry. Yoshizawa-Fujita, M., MacFarlane, D.R., Howlett, P.C. and Forsyth, M. *Electrochemistry Communications* 2006, 8(3), 445-449. **IF = 3.388**

48. Characterization of the Lithium Surface in N-Methyl-N-Alkylpyrrolidinium Bis(trifluorom ethanesulfonyl)amide Room-Temperature Ionic Liquid Electrolytes. Howlett, P.C., Brack, N., Hollenkamp, A.F., Forsyth, M. and MacFarlane, D.R. *Journal of the Electrochemical Society* 2006, 153(3), A595-A606. **IF = 2.190**

49. Fast Ion Conduction in an Acid Doped Pentaglycerine Plastic Crystal. Long, S., Howlett, P.C., MacFarlane, D.R. and Forsyth, M. *Solid State Ionics* 2006, 177(7-8), 647-652. **IF = 1.571**

50. High Mobility I-/I.hivin.3 Redox Couple in a Molecular Plastic Crystal: A Potential New Generation of Electrolyte for Solid-State Photoelectrochemical Cells. Dai, Q., MacFarlane, D.R. and Forsyth, M. *Solid State Ioncis* 2006, 177(3-4), 395-401. **IF = 1.571**

51. N-Methyl-N-Alkylpyrrolidinium Nonafluoro-1-Butanesulfonate Salts: Ionic Liquid Properties and Plastic Crystal Behaviour. Forsyth, S.A., Fraser, K.J., Howlett, P.C., MacFarlane, D.R. and Forsyth, M. *Green Chemistry* 2006, 8(3), 256-261. **IF = 3.255**

52. Novel Lewis-Base Ionic Liquids Replacing Typical Anions. Yoshizawa-Fujita, M., Johansson, K., Newman, P. MacFarlane, D.R. and Forsyth, M. *Tetrahedron Letters* 2006, 47(16), 2755-2758. **IF = 2.477**

53. Synthesis and Structural Diversity of Rare Earth Anthranilate Complexes. Deacon, G.B., Forsyth, M., Junk, P.C., Leary, S.G. and Moxey, G.J. *Polyhedron* 2006, 25(2), 379-386. **IF = 1.957**

54. Transport and Phase Dynamics of Poly(Vinyl Pyrrolidone) Doped Plastically Crystalline N-Methyl-N-Propylpyrrolidinium Tetrafluoroborate. Efthimiadis, J., Annat, G., Efthimiadis, J., MacFarlane, D.R. and Forsyth, M. *Solid State Ionics* 2006, 177(1-2), 95-104. **IF = 1.571**

55. The Nature of the Surface Film on Steel Treated with Cerium and Lanthanum Cinnamate Based Corrosion Inhibitors. Blin, F., Leary, S.G., Deacon, G.B., Junk, P.C. and Forsyth, M. *Corrosion Science*, 2006, 48(2), 404-419. **IF = 1.922**

56. Electrochemistry at Negative Potentials in Bis(trifluoromethanesulfonyl)amide Ionic Liquids. Howlett, P.C., Izgorodina, E.I., Forsyth, M., MacFarlane, D.R. *Z. Phys. Chem.* 2006, 220, 1483-1498. **IF = 1.161**

57. Preparation of CdSe Quantum Dots in Ionic Liquids. Newman, P.J., MacFarlane, D.R. *Z. Phys. Chem.* 2006, 220, 1473-1481. **IF = 1.161**

58. Confirmation of temperature independence in the fluorescence lifetime of the 3P0→3F2 transition in praseodymium-doped fluoride glass. Nguyen, T.B., Vella, V., Baxter, G.W., Collins, S.F., Newman, P.J., MacFarlane, D.R. *Optics Comm*. 2006, 261, 149-151. **IF =1.456**

59. TiO_2 sol-gel blocking layers for dye-sensitised solar cells. Hart, J.N., Menzies, D., Cheng, Y-B., Simon, G. and Spiccia, L. *Comptes Rendus Chimie*, 2006, 9, 622-626. **IF = 1.577**

60. Facile Synthesis of a new ferrocenyl uracil peptide nucleic acid monomer. Gasser, G., Belousoff, M.J. and Spiccia, L. *J. Org. Chem*., 2006, 71, 7565-7573. **IF = 3.675**

61. Reactions of iminoglycines with C60 fullerene and their unambiguous characterisation using NMR spectroscopy. Keller, P.A., Pyne, S.G., Hawkins, B.C. *CR Chim*, 2006, 9, 1100-1106. **IF = 1.577**

Appendix XI: Schedule E

Schedule E: Key results and performance measures

Key Result Area	Performance Measure	Target	2005 July-	2006Outcome
Research findings				
	Quality of publications	At least 50% of journal articles in journals with impact factor >2	No target	33
	Number of publications	2006 – 30 2007 – 35 2008 – 40 2009 – 45 2010 – 50	No target	61
	Number of provisional patents lodged	2 per annum	2	10
	Invitations to address and participate in international conferences	6 per annum	0	18
	Invitations to visit leading international laboratories	6 per annum	0	22
	Number and nature of commentaries about the Centre's achievements	Print, radio, TV media, 1 per annum	8 in Print	21 in print, 2 website, 8 radio, and 5 TV
Research training and professional education				
	Number of postgraduates recruited	20 over 5 years	30	27
	Number of postgraduate completions	4 per annum	0	4
	Number of Honours students	-	0	1
	Number of professional courses	1 per annum	0	2
	Participation in professional courses	-		
	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
International, national and regional links and networks				
	Number of international visitors	4 per annum	14	73
	Number of national and international workshops	1 per annum	0	1
	Number of visits to overseas laboratories	6 per annum	1	22
End-user links				
	Number & nature of commercialisation activities: Licences, assignments or options.	1 per annum	0	0
	Number of government, industry and business briefings	2 per annum	12	3

	Number of Centre associates trained/ing in technology transfer and commercialisation	2 per annum	1	2
	Number and nature of Public Awareness programs	1 per annum	1 Uni at the Brewery. 1 pod-cast. 1 Science EXPO. 1 school visit.	5 in 2006: Innovation Week, UoW Professorial Lecture series,Young Science Ambassadors Awards, ATS Health Technology Expo, and UoW Higher Degree Research Student Conference.
Organisational support				
	Annual cash contributions from Collaborating Institutions/Organisations	UoW $712.6K indicative p.a. Monash $257K indicative p.a. BEI $0 SVHM $0 NSW Dept of State & Regional Development $48,984 p.a. until 2007	UoW $310,000 Monash $95,000 NSW Dept of State & Regional Development $48,984	UoW $437,161 Monash $258,000 NSW Dept of State & Regional Development $48,984
	Annual in-kind contributions from Collaborating Institutions/ Organisations	Years 1 to 5: UoW $3,835,129 $1,093,753 $1,120,223 $1,146,511 $1,173,048 Monash $569,424 $583,869 $598,411 $613,051 $627,791 BEI $596,751 $487,451 $512,739 $539,391 $567,477 SVHM $553,812 $570,426 $587,539 $482,138 $498,612 NSW Dept of State & Regional Development $0	UoW $526,718 Monash $252,878 BEI $62,005	UoW $692,111 Monash $461,566 BEI $557,804 SVHM $618,198

	Number of new Organisations recruited to or involved in the Centre	3 over 5 years		7 recruited: Cap-XX, Schefenacker, CRC Polymers, DLG Battery (Shanghai) Ltd, Guangzhou Delong Energy Tech Ltd (China), CSIRO cluster, DSTO.
	Level and quality of infrastructure provided to the Centre	-		
	Annual cash 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.
	Quality of the Centre strategic plan	Evaluated by IAB		
	Effectiveness of arrangements to manage Centre nodes	Centre Exec to meet 4 times per annum	2	6 meetings held.
	The adequacy of the Centre's Key Performance Measures	Evaluated by IAB		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.
	Case studies of economic, social, cultural environmental or other benefits	1		

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.

Appendix XII: Minutes of IAB 06 Meet.

Minutes of the International Advistory Board Meeting

Convened on 15 February 2006
University of Wollongong.

Meeting commenced at 6:33pm

IAB Members Present:
Prof Ray Baughman (Acting Chair), Prof Siegmar Roth, Dr Greg Smith, Prof Peter Robinson, Dr Albert Mau, Prof Andrew Holmes, Prof Richard Kaner.

ACES Executive Committee Members Present:
Prof Gordon Wallace, Prof Maria Forsyth, Prof Graeme Clark, Prof Doug MacFarlane, Prof Leon Kane-Maguire, Ms Kaylene Atkinson, Dr Peter Innis, A/Prof Chee Too, A/Prof Will Price

Apologies:
Prof Alan MacDiarmid, Prof Edwina Cornish, Prof Margaret Sheil, Prof Naoya Ogata

1. Previous Minutes

Dr Greg Smith enquired about the action items in the previous minutes.

• He requested that the 2004 IAB report submitted to the ARC be circulated to all IAB members. **Action:** Chee Too to circulate the IAB report.

• NANOVIC has been evaluated by Profs Gordon Wallace, Maria Forsyth and Doug MacFarlane. They have found as expected that NANOVIC is only interested in funding short term R&D.

2. Presentation of 2005 Annual Report

Prof Wallace informed the IAB that the annual report presented to them is for the whole of 2005. The activities of the 2005 year, however, correspond to ACNE (January to June) and ACES (July to December).

Prof Gordon Wallace presented several highlights of the research:

• Prof David Officer will be joining the UoW node of ACES in 2007; bringing with him expertise in the synthesis area.

• A carbon nanotube synthesis facility has been established by Drs Jun Chen and Andrew Minett.

• Electrospinning of conducting fibres – SIBS on a project with Boston Scientific (USA).

• New CNT-biomolecule structures: Cell culturing with BEI/St Vincent's Health.

• CNT reinforced polyaniline fibres.

• Stuffing conducting polymers with Drs Keld West and Bjoern Winther-Jensen.

• Chiral proliferation from nanodimensional platforms.

• Control of polymer morphology using ionic liquids as solvents.

• CdSe quantum dots from ionic liquids.

Prof Maria Forsyth also presented the following highlights:-

• Nanocrystalline Ag and SnO_2 as anode materials for Li-ion batteries.

• Nano-Ionics: Gel electrolytes based on Decorated SiO_2 nano-particles.

• Conductivity enhancement in Plastic Crystal Electrolytes with nano-sized inorganic filler - Space Charge Effect?

• Zwitterion effect on SEI layer in Li metal cells.

• Surface Films Corrosion Protection - Other light metals eg Mg alloys.

Prof Graeme Clark defined Bionics as the interface between chemistry and biology where there is current moving to/from biological tissue. He presented highlights from the Bionics Program:-

• Neurite Outgrowth vs NT-3 Concentration. The aim is to have directed repair by use of polymer scaffolds; e.g. spinal cord repair. Investigations include:

• Cell Adhesion Molecules & NT-3/PPy – It was found that adhesion molecules help the nerve cells to grow over PPy.

• Internal structure of polymer contains channels to facilitate neurotrophin release.

• Differentiated SH-SY5Y cells express neuronal proteins.

• NT-3/PPy electrical stimulation shows that there is a need to find the correct level of current and voltage.

• Prof Clark also emphasized the need for safety in these applications.

3. 2006 Activity Plan

Prof Wallace informed the IAB that ACES has been signed off and back dated to 1st July 2005. He presented the following activity plan for 2006:

• ACES Milestones as Detailed in IAB Report.

• Establish Funding Base for Biofuel Cells / Biobatteries.

• Continue to Attract High Calibre Staff and Visitors.

• Strengthen Expand Research / Commercial Collaborations.

• Establishment of an End Users Group is a possible activity.

4. ACES Links and Other Funding Sources

ACES have extensive Industry Connections and

Collaborative Research links. Prof Robinson advised that now is the time to quantify and prioritise these links. For example: How active?, how much funding?, where is ACES a leader?, what is ACES impact in the area?, and what are the expected outcomes for ACES?. ACES should focus on areas of strength and exit areas where there is least impact.
Action: Gordon Wallace to quantify and prioritise to circulate to IAB for comment.

Other funding opportunities include the US Air Force Research Office (Far East), ARC funding of other areas outside ACES, Australian Government funding of nanotechnology.

5. 2006 Research Training and Prof Education

Associate Professor Will Price outlined the training and education program for 2006 as follows:

• Short-course workshops organised in key areas eg specific materials synthesis/ assembly; characterization techniques; electrochemical mapping.

• Professional training of post-graduate students in IP and commercialization via seminars, short courses and where appropriate industry placements.

• Encourage research training of post-graduate through spending time at partner institutions / institutions o/s. Give support and sponsorship for this.

• ACES involvement in research training and supervision of Nanotechnology/Chemistry and Materials Engineering Students.

6. Business Development Initiatives

Ms Kaylene Atkinson outlined the ACES business development initiatives for 2006. ACES will seek to attract companies to join as Affiliate Members for a membership fee of $10,000 p.a. Ms Atkinson provided a list of benefits for Associate Members. Prof Baughman advised that "Promotion/branding" be removed from the list of benefits because some companies would not like to be named without prior permission.
Action: Kaylene Atkinson to remove.

The IAB was of the opinion that Affiliate Membership should have 1 entry price and 1 package of benefits. Another advise is to ask companies what services are worth their membership fee. It was suggested that companies will be more interested in: (1) solutions to their problems, (2) benefits to their business, and (3) IP opportunities.

For the membership drive, it was suggested to target companies that ACES already collaborate with after the list of companies has been prioritised. It was also suggested that Cochlear Limited be segregated from Boston Scientific because they are competitors in similar fields.

7.Any Other Business

Prof Baughman congratulated the Centre on their 2005 publications total of 73 with 45 having an impact factor greater than 2; this is in comparison with the KPM target of 30 and 15 respectively.

Meeting ended at 9:16 p.m.

Appendix XIII: IP Register

ACES Intellectual Property Register

Centre Milestones	Organisation	Names of Inventors	Intellectual Property (IP) Details		Date
			Background IP	New IP	
31	UoW/IPRI	G.M. Spinks,G.G. Wallace,D. Zhou	PCT/Au02/01608, "An electrochemical actuator and means of providing same".		Nov.2001
35	UoW/ISEM	G.X. Wang, K. Konstantinov, H.K. Liu, S.X. Dou	Innovation Patent No:2002100000 "Cathode materials for rechargeable batteries and a process for production"		Jan.2002
35	UoW/ISEM	S.X. Dou, K. Konstantinov, H.K. Liu, G.X. Wang	Innovation Patent No: 2002100190, "Fabrication of cathode materials for li-ion batteries"		Mar.2002
35	UoW/ISEM	K. Konstantinov, G.X. WangH. K. Liu, S.X. DouS. Bewlay	Innovation Patent No:200 2100403"Development of new positive compounds for lithium-ion batteries"		May2002
1	UoW/ IPRITrinity College Dublin	G.G. Wallace, S. Moulton, A. Minett, W. Blau	Provisional patent. PCT lodged, "Use of biomolecules as selective dispersants for carbon nanotubes".		Feb. 2003Feb. 2004
15	Monash/CSIRO	P. Howlett, T. Hollenkamp, D. MacFarlane and M.Forsyth	PCT/AU2004/ 000263Energy Storage Devices		Mar.2004
15	UoW/IPRI/ Virginia Tech	M. Bennett, D. Leo, G. Spinks, G. Wallace	US Patent Ionic solvents for ionic polymer transducers		Aug 2004
23, 41	Monash	P. Howlett, D. MacFarlane, M.Forsyth	Aust. Prov. Patent, 2005901074 "Ionic liquid surface treatments for reactive metals and their alloys"		Mar2005
15	UoW/IPRI	Wallace, G.G., Innis, P.C., Mazurkiewicz, J., Edwards, S.	Provisional Patent Application No. 2005903481. "Charge Conducting Medium"		July2005
16	Monash/CSIRO	N. Byrne, P. Howlett, T. Hollenkamp, D. MacFarlane and M.Forsyth	US Provisional Patent Application No. 60/603524 (20 Aug 2004)PCT AU2005 001237 "Zwitterionic Additives for Electrochemical Devices"		Aug 2005
16	Monash/CSIRO	D.R. MacFarlane, A.F. Hollenkamp, P.C. Howlett, M. Forsyth, C. Tiyapiboon-chaiya, J.M. Pringle & N. Byrne,		PCT Int. Appl. 70 pp. "Zwitterionic Additives for Electrochemical Devices"	2006

Appendix XIII: IP Register

	UoW/IPRI			Provisional Patent "Biocompatible Composites"	3rd February 2006
	UoW/IPRI			Provisional Patent "Self Powered Sensing Devices"	6th February 2006
	UoW/IPRI	Diamond, D., Shepherd, R., Smyth, C., Wallace, G.G., Spinks, G.M., Wu, Y.		US Provisional Patent Application No.: 60/772,627."A Self-Maintained Sensor using a Low Power Actuator"	13th February 2006
	UoW/IPRI			Provisional Patent "Polymer Materials and Uses Thereof"	April 2006
12	IPRI/BEI	Chen, J., Minett, A., Wallace, G.G., Clark, G.M.		Aust. Prov. Patent 'Nano structured composites', AU2006907002	30th June 2006
	UoW/IPRI			Provisional Patent "Polymeric Nano composites"	13th November 2006
12	IPRI	Chen, J., Minett, A., Wallace, G.G.		Aust. Prov. Patent 'Nano composites', AU2006903544	14th December 2006
	BEI/Monash	Graeme M. Clark, David B. Grayden,		Electrophonic Hearing Patent Application	2006
	BEI/Monash	Graeme M Clark		An Implantable Device and an Implantation Process	2006
	BEI/Monash	Graeme M Clark, David B Grayden		Nanostructured Conductive Biomaterials	2006