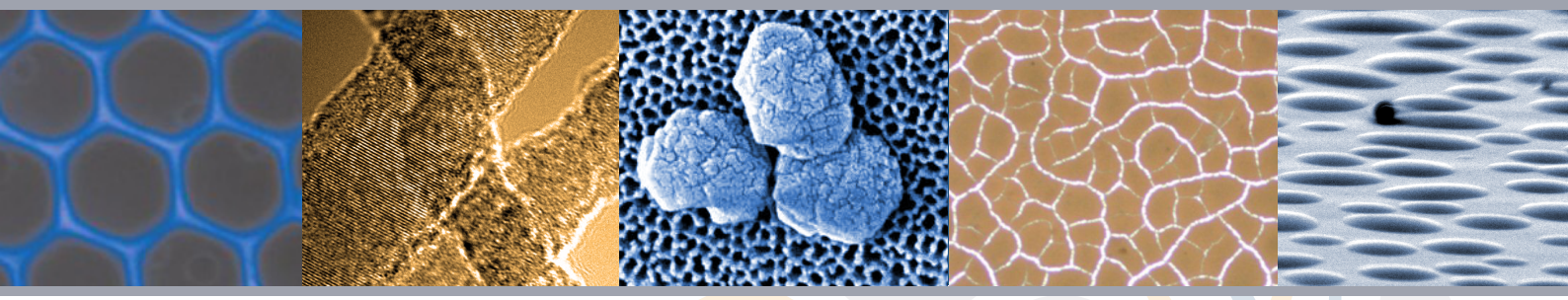
THE UNIVERSITY OF MELBOURNE

MELBOURNE MATERIALS INSTITUTE



Melbourne Materials Institute

Annual Report

2011

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Enquiries for reprinting information contained in this publication should be made through:
the Editor,
Melbourne Materials Institute
The University of Melbourne
Victoria 3010
t +61 3 8344 6415
f +61 3 9347 4783
Editor: Annabelle Pontvianne
Design: Jeanette Dargaville
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Front cover images, from left to right:

1. Extract of a visual presentation of a method for the preparation of photoresponsive, metal absorbing, and ordered porous materials. (L. A. Connal, G. V. Franks and G. G. Qiao)
2. False colour TEM images illustrating the perfectly crystalline structure of a nanowire core. (J. Fang)
3. False colour SEM images of diamond-like carbon on the surfaces of freestanding anodic aluminum oxide template. (J. Fang)
4. Optical micrograph of titania nano-particle dry thin film showing the macroscopic mud cracks when processed from low volume fraction solids suspensions. (S. Tanurdjaja, X. Zhang, G. V. Franks)
5. SEM images of nanolenses prepared by in-situ polymerisation. (X. Zhang et al.)

Back cover images, from left to right:

1. Isolated diamond electrodes for the high-acuity bionic eye device. (K. Ganesan)
2. False colour image of micropipette aspiration of porcine cartilage cell. (P. Lee)
3. False colour SEM images of diamond-like carbon on the surfaces of freestanding anodic aluminum oxide template. (J. Fang)
4. False colour SEM image of alumina template on quartz. (J. Fang)
5. False colour SEM images of AAO template. (J. Fang)

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Introduction

Today's materials research. Tomorrow's technology.

Innovations in material science underlie so many of the developments that we take for granted in our day-to-day lives: solar panels on our roofs, pacemakers in our bodies and membranes for waste water filtration. The University of Melbourne has deep expertise in a broad range of materials science and engineering disciplines. The Melbourne Materials Institute (MMI) was established in 2009 to promote and increase the impact of this research.

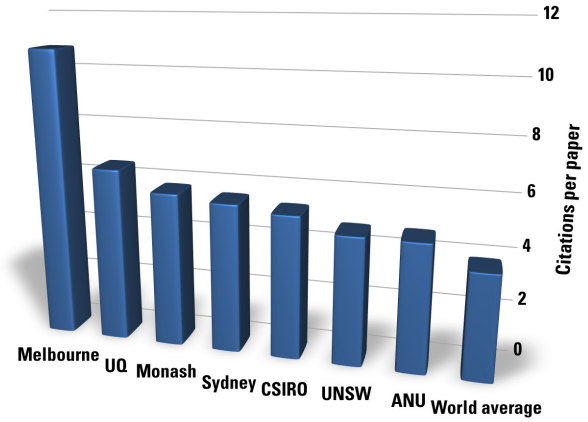
The MMI is committed to achieving this by bringing together researchers from a range of disciplines across the University and by acting as the entry-point for industry seeking to work with materials researchers on innovative solutions. The Institute aims to establish partnerships with industry and to use its expertise to turn problems into solutions and deliver sustainable and practical applications.

The MMI's mission is to establish the University of Melbourne as a major player in materials research on the international, national and regional stage. The Institute seeks to be recognised by governments, the research community and industry, for its excellence in fundamental and applied research and its ability to deliver enabling technologies to benefit humanity.

This edition of the MMI's annual report highlights both the activities of the MMI and the outstanding achievements in materials research across the University of Mlebourne in 2011. The research presented in this report has been funded by various sources, including the Australian Research Council (ARC), the National Health and Medical Research Council (NHMRC), the MMI and the University.

The objectives of the MMI are:

- to be a portal for materials science at the University of Melbourne
- to showcase materials research at the Universityof Melbourne
- to foster interdisciplinary discussion and collaborations with a materials focus
- to create internal and external linkages
- to capture materials innovations for the benefit of the broader community.



Citation impact: the University of Melbourne is leading Australia's Materials Science output, as classified by Thomson Essential Science Indicators, with more than three times the world average for impact (citations per paper) in the period 2007-2011.

Director's report

Welcome to the second annual report of the MMI. As you browse through the pages of the report, we hope that you will become aware of the values that the MMI and its members celebrate: outstanding and innovative research, effective communication of the breadth and depth of materials research across the University, mentoring and support for early career researchers and success in the development of deep partnerships with key industries and governments. Let me take a moment to comment on each of these.

Even a cursory glance at the Interdisciplinary Seed Funding projects supported by MMI reveals the creativity that can be unlocked when experts from different disciplines work together. From invisibility cloaks to wireless strain gauges for dentistry, the portfolio is a wonderful example of how the breadth of our research can be exploited to develop new and innovative solutions to important and pressing problems. The research is for the most part highly risky, but if successful we can expect advances in areas as diverse as the treatment of osteoarthritis, the delivery of cancer drugs and the production of cheap and flexible solar cells.

It is not only our responsibility, but also our privilege to communicate the best of our science to each other and also to the world outside the University. Internally, the MMI has done this through its annual research workshop, co-hosted events with Bio21, participation in the annual Engineering symposium, technical seminars for professional staff and 'Wine & cheese afternoons'. External events included lectures by visiting academics on topics such as targeted drug delivery systems using nanosponges and the controversial issue of water recycling. The MMI website has been revamped and we invite you to pay a visit. Of course, we always welcome your comments and reactions.

Early career researchers and PhD students are the lifeblood of our research effort both today and into the future. The MMI is proud to support PhD students through the provision of top-up scholarships and early career researchers through seed funding and other grants. We intend to enrich the life of students and postdocs by offering overseas research experience whenever possible. The MMI has led the effort to recruit some of the best and brightest students from overseas into our core programs. Such recruitment will continue to be a focus in the year to come, especially attracting students into interdisciplinary projects.

The development of partnerships is seen by MMI as pivotal to our growth and success. There is much evidence to suggest that 'connectedness' is highly correlated to 'innovation'. Only by creating linkages are we likely to increase the impact of our research. The partnerships established in 2010 continue to flourish. Of particular note is the progress made under the Bionic Vision Australia program towards the first prototype retinal implants and the establishment and development of the Defence Science Institute. Much more work needs to be done in developing an ecosystem of partners if we seek to change the materials research landscape. Thus in 2012, we will concentrate on widening our net of partners to include clusters of small and medium businesses in priority areas such as electronics and bionics.

We are indebted to the MMI team so ably led by Manager Gaby Bright and supported by Communications Officer Annabelle Pontvianne, Project Officer Lillian Tan and Technical Support Manager Irving Liaw. Without their dedication and professionalism, the MMI would not be the success it is today. Special thanks go to Annabelle for her outstanding work on this annual report.

The year ahead promises to be full and fulfilling. Our core themes will be reviewed and expanded to include areas such as art conservation and bionics. We will roll out our platform support program designed to provide critical infrastructure support and we will develop a comprehensive materials research capability statement for the University. As always, we welcome (and depend on!) your input, feedback and participation. We look forward to working with you in 2012.

S. Prawer

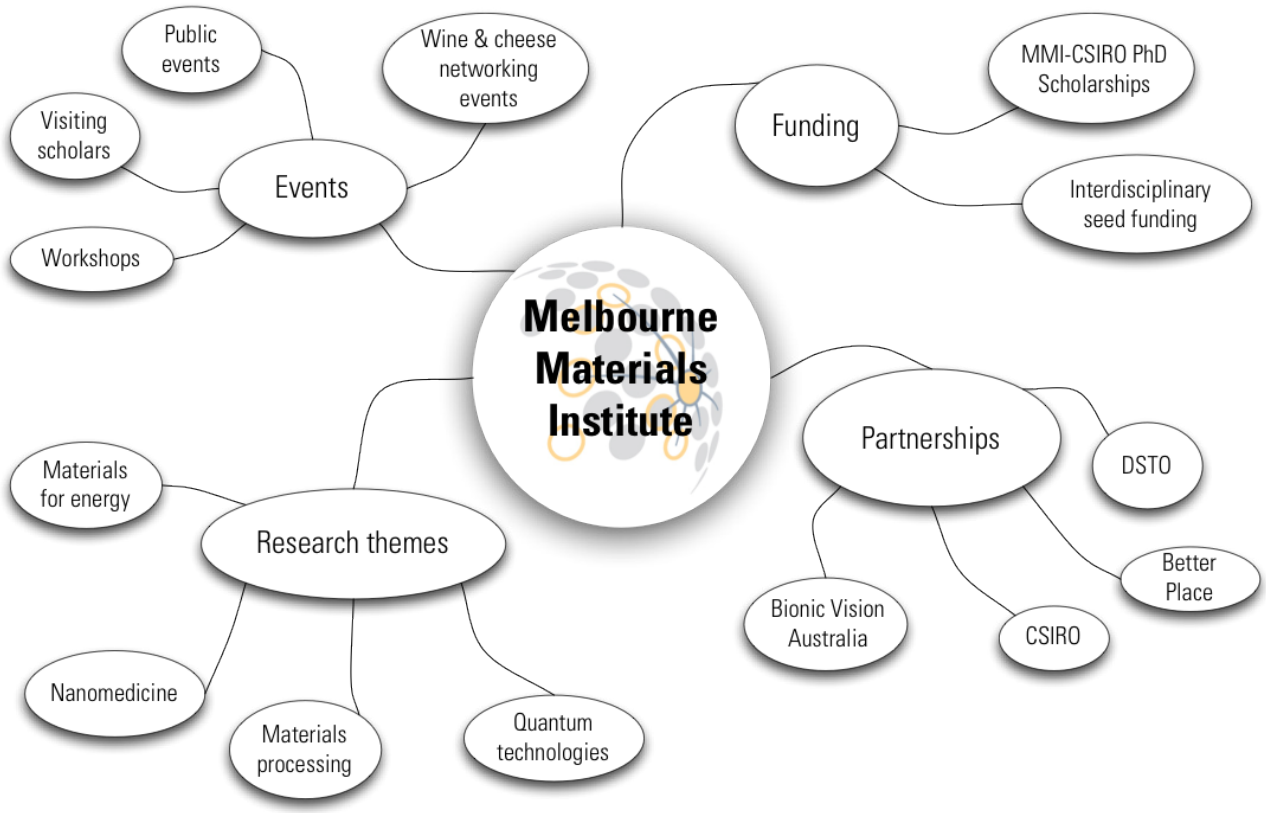
Steven Prawer, MMI Director.

Program map

The MMI captures much of the materials research strengths of the University under the broad umbrella of the research themes: Nanomedicine, Materials for energy, Materials processing and Quantum technologies. The MMI supports the full breadth of materials research by:

- providing Interdisciplinary Seed Funding
- facilitating research workshops and networking events
- hosting and financially supporting visiting scholars and
- managing PhD scholarship programs.

The Institute raises public awareness on materials advances and their implications on society by holding public events and contributes to the University's external engagement, through partnerships with organisations such as Bionic Vision Australia and the CSIRO.



2011 in review

This section presents an overview of MMI's activities and achievements in 2011, followed by a review of some of the University's materials research successes and media mentions.

Governance

The MMI has established an Advisory Board, composed of six Australian and international members from industry, research organisations and academia. Board members provide high-level strategic advice to the Institute Director and promote the interests of the Institute to the broader community. Members contribute to the MMI's strategic planning and create opportunities for the formation of external partnerships and collaborations.

Linkages and partnerships

Establishing and nurturing partnerships and linkages is a core value for the MMI. In 2011, MMI Director Steven Prawer has been actively engaging to create new connections and interactions with internal and external stakeholders.

Throughout the year, the MMI Director has initiated a series of meetings with internal senior researchers to explore potential linkages. The departments and faculties involved include the Centre for Neural Engineering, the Faculty of Arts, the Victorian College of the Arts, the Faculty of Business and Economics, and the Faculty of Architecture, Building and Planning.

In October, the MMI, along with representatives from the Melbourne Energy Institute, Melbourne School of Engineering and Stem Cells Australia, met with the Australian Trade Commissioner from Paris (Austrade). Austrade aims to promote Australian expertise in clean-tech and bio-tech research that could form part of their Investing in Research program, linking European industry partners with Australian research expertise. The MMI highlighted the importance of materials research such as waste management, bionic devices, and nanomedicine as well as the research partnership with CSIRO.

Prof Prawer has been promoting the University's excellence in materials research to external organisations, with a view to enhancing the research capabilities of all parties and increase the amount of translational research done at the University.

In the second half of 2011, the MMI began discussions with Agilent Technologies (previously Varian), manufacturer of analysis equipment. Site visits to Agilent's Melbourne facilities have enabled the MMI and Agilent to develop a mutual understanding of their respective expertise and establish areas of collaboration. Agilent invited the MMI to submit a research proposal for evaluation, on behalf of the University.

Charge spots for electric vehicles. (Better Place Australia)

Better Place Australia

The University's shift to electric vehicles, encouraging less reliance on oil, proceeded in 2011 through the relationship with Better Place Australia. Discussions are continuing about the installation on campus of charge spots for electric vehicles. The MMI Director and representatives from Property and Campus Services attended the Better Place Australia launch at the Australian Motor Show. Attendees were given a demonstration of the charge spots and the new models of electric vehicles soon to be available in Australia. This occasion allowed for further development of the relationship between the University of Melbourne and Better Place Australia.

Governance, linkages and partnerships

Defence Science Institute (DSI)

From 2009, the MMI served as the incubator of the DSI, with Prof Prawer acting as Interim Director from the time the DSI was launched, in October 2010, until the appointment of Prof Bill Moran as Research Director in 2011.

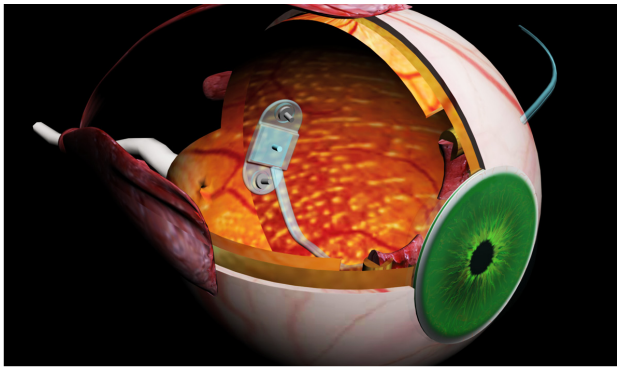
The mission of the DSI is to build stronger linkages between the Defence Science and Technology Organisation (DSTO), all universities in Victoria, and Victorian industry, with an emphasis on small to medium enterprises. The Institute is building defence research networks that support the nation's defence and national security capability.

The DSI had a significant presence at the 2011 Avalon Airshow. The Institute held several workshops throughout the year, across a range of topics, with visits from the US Assistant Secretary for Chemical, Biological and Nuclear Defense and the Head of the Defense Threat Reduction Agency, as well as from two visitors from international universities. The DSI supported four STrategic Research Australian Postgraduate Awards (STRAPAs), a Discovery Early Career Researcher Award (DECRA) and three Future Fellowships in the University of Melbourne and Monash University. In line with its mission, the DSI has begun discussions with several other Victorian universities to join the Institute. 6+In June, the DSI, the MMI and the Bio21 Institute hosted a visit from the five member-country Technical Cooperative Panel (TCP). The TCP brings together DSTO and equivalent defence organisations from the UK, US, Canada and New Zealand. The discussion covered collaboration opportunities between TCP members.

The DSI shared a stand with the State Government at the Avalon Air Show.

Bionic Vision Australia (BVA)

BVA has made much progress with the development of both its wide-view and high-acuity retinal implants. Researchers associated with the MMI have fabricated BVA's first electrode array with physically and electrically isolated electrodes and developed techniques to fabricate feedthroughs connecting the electrode array with the microchip. The team has also optimised the laser milling of diamond material to make a box that will encapsulate the device.



Artist's impression of the current generation of the BVA epiretinal device, tacked in positioned over the macular. (D. Garrett)

International academic delegations

The MMI engaged with the International Relations Office to host a visit to the University of Melbourne by a senior delegation from the University of Science and Technology of China in April. Prof Prawer and Prof Jamieson (Head of the School of Physics) gave the Chinese delegation a presentation of the MMI and UoM's activities and capabilities, while Dr Spizzirri led the group through a visit of strategic research laboratories.

The University hosted a 'Fact Finding Mission' to Australia by the German Baden-Württemberg Network for Functional Nanostructures. Whilst in Melbourne, the delegation visited the Bio21 Institute, the School of Physics and the Melbourne Centre for Nanofabrication. An afternoon series of presentations allowed the Network to present their work and to learn about the research undertaken by professors Hollenberg and Prawer. The Network has previously supported research at the University and the visit will enable future collaboration.

Research funding and support

Interdisciplinary Seed Funding

As part of the University's Interdisciplinary Seed Funding scheme, the MMI has supported six materials-related research projects in 2010 and twelve in 2011. The MMI hosted two lunches for the grant recipients in August, to review progress and identify ways in which the Institute can further support the development of their projects, beyond the seed funding stage.

Materials Science PhD Scholarship program

The MMI-CSIRO Materials Science PhD Scholarship program, started in late 2010, has resulted in the provision of fifteen PhD scholarships to excellent domestic and international students. The research areas encompass nanomaterials, nanomedicine, biotechnology and embryology. All recipients have been matched with both UoM and CSIRO supervisors. The scheme has been highly successful as both a recruiting tool for international students and as a means of forging closer links between CSIRO and the University.

Particulate Fluids Processing Centre (PFPC)

The MMI committed to fund $50,000 to the PFPC in 2011 and 2012. The PFPC is a Special Research Centre of the Australian Research Council (ARC) based at the University of Melbourne. The PFPC brings together a multidisciplinary team whose research programs pioneer understanding of the interactions at the interfaces between particles and the fluids within which they are dispersed.

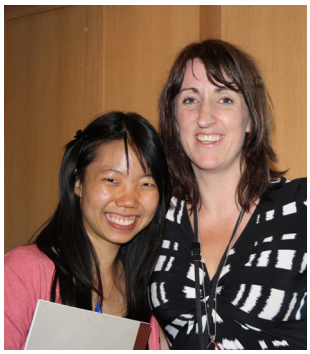
The MMI funds helped to support a fortnightly seminar series run by the postgraduate students and an annual symposium and workshop. In 2011, the workshop 'The Future of Research Funding in Universities - Who will be the Winners and Losers?' included an international contributor, Professor Brian Vincent, who was able to give a global perspective on the issue. The financial contribution from the MMI was also used towards vacation studentships and travel grants for postgraduate students and postdoctoral researchers.

MMI's financial contribution was used toward PFPC travel grants. The grants helped postgraduate students like Davide Ciceri and William Lum to attend international conferences such as *ISEC2011: 19th International Solvent Extraction Conference*, Santiago, Chile, 3-7 October 2011.

Education

The MMI collaborated with the Faculty of Business and Economics to connect engineering students into the Volunteer Based Practicum program. The program brings together small groups of students from a range of disciplines including business, finance and IT, to apply their skills in a practical setting. During the semester break, an engineering student provided scientific input to a project undertaking a cost-benefit analysis for bioenergy options in a health precinct in Ballarat.

The MMI provided financial support to two students undertaking a summer internship with Drs Georgina Such and Angus Johnston in the Department of Chemical and Biomolecular Engineering. Adelene Wong and Chloe Miller spent their summer break respectively working on the development of new strategies for the assembly of polymeric delivery systems, and investigating antibody targeting for improved vaccine therapies.



"Thanks to the MMI, I have been privileged to be working this summer under Dr Such. It has succeeded in opening my eyes towards materials research, and I have enjoyed it immensely." Adelene Wong, summer intern.

Summer intern Adelene Wong with supervisor Dr Georgina Such.

Technical infrastructure

The MMI is establishing a Platforms Development Group which aims to deliver enhanced research outcomes through the provision of platform support and development. This pilot program, to be rolled out in 2012, will develop the framework for three platforms, with a view to facilitating access and inter-faculty collaboration and to developing a user community. The program will be led by research-active Academic Platform Leaders, supported by the MMI's Technical Support Manager and a team of Platform Support Officers.

International visitors

The MMI hosted three international visiting cademics in 2011.

The Institute supported the visit of Prof Ludwig Gauckler (ETH-Zurich), organised by the Melbourne Engineering Research Institute (MERIT). Prof Gauckler gave a colloquium entitled 'Colloid Chemistry for Innovations in Ceramic Science and Technology' on 16 February.

A/Prof Eva Harth (Vanderbilt University (VU)) visited the MMI from 12 to 21 May and gave a well received public lecture on nanosponges for drug delivery. This visit has resulted in a number of plans to collaborate across the University. They include prospective collaborations with: Andrew Kaye (Dept of Surgery); the Department of Ophthalmology & Visual Sciences - a VU-UoM grant application was drafted during the visit; Frank Caruso (Dept of Chemical and Biomolecular Engineering); Mark Cook (Dept of Medicine, St Vincent's Hospital) - Prof Cook invited A/Prof Harth to present at a conference in Sydney next year; and Brian Smith (Walter and Eliza Hall Institute for Medical Research (WEHI)).

A/Prof Harth returned to the University of Melbourne in November, as an invited speaker to the MMI 'Nano in medicine symposium'. As part of her MMI-hosted visit, she met with collaborators from the departments of Chemical and Biomolecular Engineering and Ophthalmology, as well as from WEHI.

Prof Chris van de Walle (UCSB) visited the University and presented on the work that his computational materials research group is undertaking during a well attended colloquium at the School of Physics on 17 May.

Event and workshop support

The MMI supported the symposium 'Scoping the future of cultural enrichment through cultural materials conservation' held on 16 June by the Centre for Cultural Materials Conservation (CCMC).

The MMI hosted and sponsored a plasmonics workshop at the University on 10 October. The workshop brought together plasmonics researchers from Monash University, CSIRO, the Materials Science Institute (Madrid) and the Queensland University of Technology. Participants discussed current research and collaboration opportunities and the potential for Australia to host the next international plasmonics conference.

Events

Speakers and the organiser of the 'Nano-in medicine symposium' co-hosted with the Bio21 Cluster on 14 November. From left to right: A/Prof Eva Harth, Dr Simon Corrie, Prof Maria Kavallaris, Prof Peter Choong, Dr Stella Clark, Prof Steven Prawer.

Research workshop

The MMI held its annual materials research workshop 'Materials Challenges for the 21st Century ' on 24 August at Graduate House. This successful event brought together 90 researchers from the University and over 30 external partner research organisations, to explore topics for collaboration. It was opened with a plenary talk from the Dean of Science and was followed by six presentation sessions, covering nanomedicine, defence materials, bionic devices, nanomaterials, materials processing and materials conservation. The Pro Vice-Chancellor (Research Collaboration) spoke about the value of research collaboration to the University and encouraged researchers to apply for the Interdisciplinary Seed Funding scheme.

Co-hosted events

On 14 November, the MMI and Bio21 Cluster co-hosted the 'Nano-in-medicine' symposium, held at the Melbourne Brain Centre. This event featured speakers from Vanderbilt University, the Australian Centre for Nanomedicine and the Australian Institute for Bioengineering and Nanotechnology. It provided a high-level overview of current trends in nanotechnology with potential applications to human health. Four sessions were conducted in the following areas: 'Nanostructures and scaffolds in medicine', 'Nanomaterials and drug delivery', 'Underpinning technologies' and 'Nanomedicine in practice'.

Participation in events

The MMI presented at and supported the running of the 2011 Melbourne Engineering Research Institute (MERIT) Symposium on 13 May. As part of this event, a workshop on 'Transformational Energy Technologies', lead jointly by Prof Prawer and CSIRO Acting Deputy Chief (Materials Science and Engineering Division) Scott Furman, explored new research opportunities that would increase efficiencies in energy use. In particular, the workshop explored novel technologies for the smelting of aluminium. It was noted that if the amount of electricity required to make aluminium could be reduced by 25 to 30% through efficiencies in the process of electrolytic reduction of alumina, there would be a reduction in the world's electricity usage by 1%.

The MMI participated in Interact on 22 July. The event presented research success stories, showcased successful 2011 Interdisciplinary Seed Funding projects and provided a forum for potential new collaborations. Interdisciplinary materials research was presented by the MMI Director and by the researchers themselves as part of the poster session. Feedback from the participants was overwhelmingly positive, with a call for more opportunities for researchers to meet others outside their discipline.

The second international conference on medical bionics 'Neural Interfaces for Damaged Nerves' was held at Phillip Island from 20-23 November. MMI Director Steven Prawer was a keynote speaker, and the University and the MMI were major participants and sponsors. The activities of the University's bionic eye project were featured throughout the conference.

Technical seminars

The MMI's Technical Support Manager has started a unique series of technical seminars focusing on research equipment and associated technology. The first seminar was held on 14 October. An audience of Research Higher Degree students, technicians and research staff from the faculties of Science, Engineering and Medicine was given a presentation of the development of vacuum equipment by Dave Kelly, an Applications Engineer for MKS Instruments. The presentation, supported by John Morris Scientific, was followed by a short Q&A session, where attendees discussed the application of the presented equipment to their own work. Further to the first seminar's success, the series will continue in 2012 on a monthly basis.

Wine & cheese afternoons

The MMI held quarterly 'Wine & cheese afternoons'. Intended to generate encounters between researchers that may not happen otherwise, this informal networking event aims to encourage interdisciplinary discussions and foster new collaborations across disciplines. The format of the event consists of a twenty minute talk followed by informal discussions over refreshments. The themes and speakers were:

- 'Strange bedfellows, nanoscience and cultural conservation' by A/Prof Robyn Sloggett, Director of the CCMC (24 March).
- 'Green computing' by Prof Peter Taylor, Director of the Victorian Life Sciences Computation Initiative (VLSCI) (23 June).
- 'Multidisciplinary careers' by Prof Field Rickards, Dean of the Graduate School of Education (9 September).
- 'Nanocapsules: new materials for better health outcomes' by Dr Georgina Such, 2011 L'Oréal Women in Science Fellow (Dept of Chemical and Biomolecular Engineering) (16 December).

The last Wine & cheese afternoon for 2011 was also an opportunity for the MMI Director to review and acknowledge 2011 materials successes by University researchers.

The Wine & cheese afternoons have successfully attracted an interdisciplinary audience, with attendees from a range of faculties and organisations including the schools of Engineering, Physics and Chemistry, VLSCI, IBES, CEET, NeCTAR, CSIRO, IBM and the Baker IDI Heart and Diabetes Institute.

Public events

On 16 May, A/Prof Eva Harth (VU) gave a well-received public lecture about the use of nanotechnology for targeted drug delivery entitled 'Nanosponges for Targeted Cancer Treatment'. An interview of A/Prof Harth, discussing with Dr Angus Johnston (Dept of Biomolecular and Chemical Engineering) how cancer treatments may be vastly improved through drug delivery at the nanoscale, is available on the online University talk show Up Close (24 June) .

A/Prof Eva Harth (VU) gave a public lecture on nanosponges for targeted cancer therapy. (Casamento Photography)

The MMI held its second public event on 6 October, 'From toilet to tap' with MMI Theme Leader Prof Peter Scales the main speaker, joined by two eminent panellists. Prof Scales gave an overview of the technology, the challenges and the benefits of water recycling. Adam Bandt (Melbourne Greens MP) introduced Prof Scales' talk with a political perspective on the adoption of recycled water. Prof Michael Porter (Deakin University) concluded the presentation by taking a public policy and economic approach to the issue. The lecture is available online (http://bit.ly/fromtoilettotap) and was broadcast on Australia's Public Affairs Channel (A-PAC, Sky news).

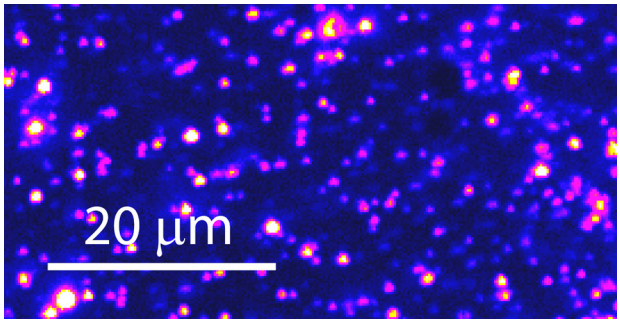
Left: The MMI held a public event giving political, technical and economic perspectives on water recycling. From left to right: Prof M. Porter (Deakin University), Prof P. Scales (University of Melbourne), Prof S. Prawer, Dr A. Bandt (The Greens MP). (Casamento Photography)

University materials research successes

Achievements, awards and promotions

Notable materials successes across the University for 2011 include the following:

- Prof Frank Caruso (Chemical and Biomolecular Engineering (CBE)) and A/Prof Rachel Caruso (Chemistry) were respectively ranked 17th and 21st amongst the top 100 materials scientists in the world, according to total publication impact in the last decade (March).
- Prof Eric Reynolds (Melbourne Dental School) has received an award from the International Association for Dental Research for his research into gum periodontal disease (this research was supported by an MMI seed funding grant in 2010) (March).
- The Bionics Institute, a key partner of Bionic Vision Australia, was launched by Prime Minister Julia Gillard launched (June).
- Prof Robin Batterham was nominated as one of Australias' 100 most influential engineers in the 2011 ranking from Engineers Australia (June).
- PhD student Brandon MacDonald (Bio21 Institute) received a 2011 Fresh Scientists award for his work on nanocrystal inks for solar cells (June).
- Dr Jing Fung Tan (CBE) was awarded a Chancellor's Award for Excellence for his PhD thesis, which examines methodologies for producing star-shaped polymers (August).
- Dr Georgina Such (CBE) was the recipient of one of three L'Oréal Australia Women in Science Fellowships for her work on a targeted drug delivery system using nanocapsules (August).
- Dr Phong Tran (CBE) received a McKenzie Fellowship to develop new materials for soft tissue damage repair that could potentially provide a more cost-effective treatment, with fewer complications for patients (September).
- Prof Geoff Stevens was appointed Laureate Professor (September).
- Prof David Solomon (CBE) was awarded the Prime Minister's Prize for Science for his role in revolutionising polymer science (October).



Light emission from individual nitrogen-vancancy centres in hybrid diamond-glass optical fibre. (B. Gibson et al.)

- Three materials scientists were promoted to the rank of Professor: George Franks (CBE), Sandra Kentish (CBE) and Kenong Xia (Mechanical Engineering) (October).
- Dr Brett Paterson (Chemistry, Bio21 Institute) was awarded a Victoria Fellowship for his research into new diagnostic molecular agents to aid in the detection of early stage cancer. (November).

Government funding

Collective materials research expertise at the University has resulted in funding success with over $8.3 million in grants from the ARC (1 DECRA, 8DP, 3FF, 8 LP, 2 LIEF). Notable successes include:

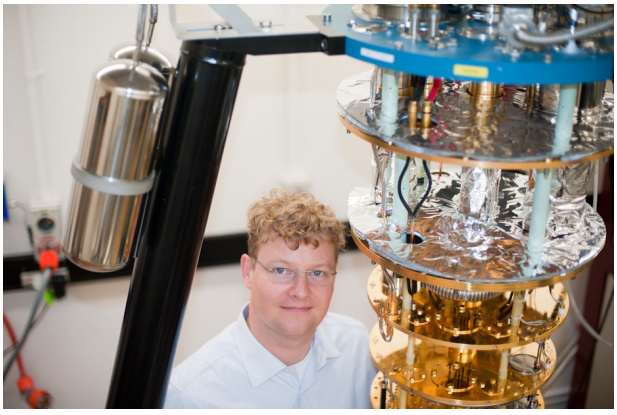
- A DECRA to Dr Jiri Cervenka to develop functionalised graphene for next generation nanoelectronics.
- Future Fellowships grants to Dr Brant Gibson, to explore hybrid nanodiamond materials for future sensing, biodiagnostic and quantum devices; to Dr Angus Johnston, to investigate how nanomaterials interact with biological systems and understand any potential side effects; and to Prof Greg Qiao, to synthesise highly complex polymer architectures for targeted applications.
- An ARC Linkage Project grant to Prof Paul Mulvaney and A/Prof Ann Roberts, with Dr Luke Maguire and Mr Wayne Jackson of Note Printing Australia, a subsidiary of the Reserve Bank of Australia, to look at metamaterials as anti-counterfeiting elements in Australian banknotes.

A further $13.8 million was awarded by state and federal governments for research into materials processing for water treatment, carbon dioxide capture and printable solar cells.

University materials research in the media

The work of materials scientists at the University of Melbourne has been showcased in University, public and academic media. Media mentions include the following:

- Prof David Jamieson (Physics) was interviewed on ABC radio (22 March), speaking about the element thorium and the possibilities of cleaner, safer thorium nuclear reactors.
- An overview of how the bionic eye will work and what patients with the retinal implant will be able to see was presented on ABC science show Catalyst (31March).
- Samantha Lichter – postgraduate student and BVA team member - featured in Channel Ten's children science show Scope edition on carbon. Samantha explained how diamonds are used in the development of the electrode array for the bionic eye (23 April).
- Following her MMI-hosted public lecture, A/Prof Eva Harth (VU) was interviewed on ABC's current affairs program 'The World today' (16 May).
- A/ Prof Harth and Dr Angus Johnston (CBE) discussed how cancer treatments may be vastly improved through drug delivery at the nanoscale on online University talk show Up Close (24 June).
- Dr Georgina Such (CBE) has featured in several print and online media including the Age (24 August) and YouTube as a recipient of the 'Women in Science L'Oreal Award' for her work on nanoengineered drug carriers.
- A unique nano-diamond sensor, the creation of Prof Hollenberg (Physics) and his team, was presented on ABC's Catalyst. The sensor could be used for tracking drugs in a living cell. Dr Yan Yan (CBE) explained how she could use Prof Hollenberg's sensor to determine how drugs interact with cells (25 August).
- The video of the MMI public lecture 'From toilet to tap' was broadcast on the Australian Public Affair Channel (A-PAC, Sky news) (http://www.a-pac.tv/). The video is also available on YouTube (http://bit.ly/youtube-toilettotap) and Live in Melbourne (http://bit.ly/fromtoilettotap). The lecture also attracted a mention on the RRR science show 'Einstein-a-go-go' and the main speaker Prof Scales was interviewed on Joy FM (October).
- Dr Laurens Willems Van Beveren (Physics) was featured in Voice, presenting a newly acquired A$600,000 cryogen-free dilution refrigerator, which can cool down to close to absolute zero (-273°C) (September).
- Prof David Solomon and Dr Georgina Such have been featured in The Age Melbourne Magazine as two of Melbourne's 100 most influential, inspirational, provocative and creative people (8 December).
- Dr Kate Fox (Physics) shared her inspirational story in Physics World, explaining how "luck, both good and bad", led her to work on the Bionic Eye project (December).



Dr Laurens Willems Van Beveren with the new cryogen-free dilution refrigerator which can create the coldest macroscopic place in Victoria. (D. Tacon)

Researcher profiles: A/Prof Andrea O'Connor

Associate Professor, Dept of Chemical and Biomolecular Engineering.

"I wish more people would recognise the difference between statistically justified scientific conclusions and anecdotal 'evidence'."

How would you describe what you do?

I run the Tissue Engineering and Nanoporous Materials Research Group in the Department of Chemical and Biomolecular Engineering. We conduct interdisciplinary research to develop materials, processes and knowhow to address challenges in tissue engineering, drug delivery, bioseparations and catalysis. I also teach Chemical Engineering and Biomedical Engineering courses and work with industry and government agencies.

What potential applications may result from your research?

Two quite different potential applications are tissue engineering of 3D soft tissues and development of new high efficiency catalysts. In tissue engineering, we aim to regrow an individual's own tissues for reconstructive surgery (e.g. after tumour removal in cancer patients) and in the longer term to facilitate organogenesis, regenerating organs such as the thymus or thyroid. Our work in hierarchically porous materials aims to develop superior catalysts and supports to enable conversion of solar energy to chemical energy and production of hydrogen from carbon-containing fuels, biomass and water with greater efficiencies than are currently available.

What do you hope to achieve in the next few years? the rest of your career?

In the next few years I hope to further our understanding of design, materials and processes to achieve 3D tissue engineering at the human scale and to continue translating this towards solving problems in medicine. I would like to see the knowledge and materials we develop having a positive impact in research with our collaborators and in industry. Over the rest of my career, I hope to see our research outcomes translating to benefits in the real world, be it in new medical devices, tissue engineering techniques or catalysts for the hydrogen economy.

What motivates you to get up every morning?

Collaboration – I get a kick out of the challenges and inspiration of working with people from a wide range of backgrounds, from engineers, chemists and biologists to surgeons and industrial partners to solve engineering problems. I enjoy seeing my students developing their skills and enthusiasm for science and engineering so they can make an impact somewhere in the world.

In your opinion, what are the main ingredients for successful research collaboration?

Collaborations need trust, respect and communication. The latter sounds easy but can be the hardest in multidisciplinary work, as we may think we understand each other but use the same words to mean different things. We found it took more than a year to really understand the surgeons and cell biologists we collaborate with in tissue engineering and sometimes we still need to stop and ask what they are talking about. So the relationship needs to be strong enough to be enjoyable and productive despite these hurdles.

What professional achievement are you the most proud of?

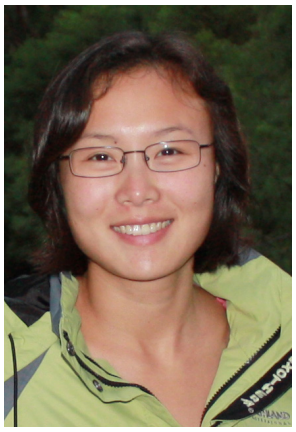
I am excited about a new method we developed to produce hierarchically porous beads, termed co-MET or co-micelle/emulsion templated materials, and was pleased to see it published and a provisional patent filed on the process in 2011. These beads, which can be made of silica or many other organic or inorganic materials, have well controlled particle, macropore and mesopore sizes, making them potentially useful in applications ranging from bioseparations and drug delivery to catalysis.

What role do you think science has to play in society?

I think an understanding of science and the scientific method is vitally important and surprisingly often lacking in the media and society. I wish more people would recognise the difference between statistically justified scientific conclusions and anecdotal 'evidence'.

Dr Yan Yan

Postdoctoral Fellow, NIMs group, Dept of Chemical and Biomolecular Engineering.



"I would like to continue to develop bio-inspired nanotechnology-enabled delivery systems that will be used to save lives and reduce the suffering from cancer."

How would you describe what you do?

My current research lies on the interface of nanotechnology and cell biology. Nanotechnology has the potential to bring many novel insights into current cell biology through engineering materials at the nanoscale. I am trying to understand how such nanoengineered materials interact with human cells to enable the development of novel nanomaterials for future translational research.

What potential applications may result from your research?

The potential applications from the fundamental research that I am focusing are broad based. It could lead to a better diagnosis and treatment for many diseases, including various types of cancer and infectious diseases.

What do you hope to achieve in the next few years? The rest of your career?

I would like to be successful in my current DECRA application and use this to continue advancing our understanding of the cellular behaviour of nanoengineered materials. I am passionate about my research, not only the fundamental aspects but also their applications. I would like to continue to develop bio-inspired nanotechnology-enabled delivery systems that will be used to save lives and reduce the suffering from cancer.

What professional achievement are you the most proud of?

I have developed the investigations on cellular interactions of polymer particles in Prof Caruso's laboratory. These studies have provided important information on intracellular dynamics of polymer particles. My studies also have shown that particle-based drug delivery can bypass multidrug resistance in cancer cells. I am also proud of a recent collaborative project involving nanodiamond-based quantum sensing in cell biology with Prof Hollenberg. I have brought biological expertise to the work and made important contributions, which led to a publication in Nature Nanotechnology.

Give us five words you would like people to associate with your name.

Professionally, I would like to be associated with nanotechnology, nanomedicine, drug delivery, cancer biology and translational medicine. Personally, I would like to be seen as being creative, dedicated, fair, fun and resilient.

If you weren't a scientist, who would you like to be?

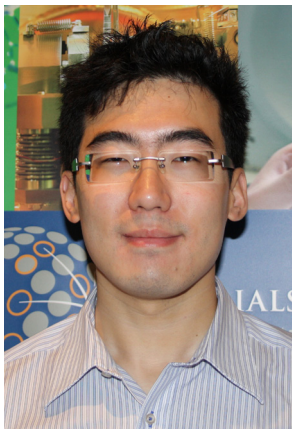
If I wasn't a scientist, I would like to be a clinician. I think this would be both interesting and challenging, and socially important because maintaining good health and reducing suffering due to diseases is essential for society.

What do you do in your free time?

I always love to travel in my holidays and experience new places and cultures. Bush walking and swimming are my favourite exercise. I also adore fine dining and find gastronomy fascinating. Since cooking is based on chemistry, to some extent elements of science are not too far away in my free time!

Mr Aaron Song

MMI-CSIRO PhD scholarship recipient



'Young students have to be exposed to science and given the opportunity to explore and appreciate its beauty.'

What did you do before undertaking your PhD?

I worked as a research assistant in a number of universities, and was exposed to a broad range of fields from chemical synthesis to semiconductor physics. I also worked as a science tutor in private education centres in Sydney and Melbourne as I always enjoy sharing my passion and knowledge in science with younger generations.

What attracted you to research in this field?

Organic molecules and optoelectronic devices had very little connection until the discovery of conducting polymers in the late 1970s. Now the work of many scientists and engineers has blossomed into the exciting field of organic optoelectronics. I have always had an interest in synthesising colourful molecules and studying the physics of optoelectronic devices, so I now wish to develop high-performance organic materials for printable devices.

What is your research on?

Although thousands of organic semiconductors have been synthesised and tested, very few demonstrated the potential to be used in large scale, commercialisable optoelectronics such as LEDs and photovoltaics. My research is focused on the design and synthesis of novel organic semiconductors. With new strategies from combinatorial material synthesis and design, I expect to synthesise a range of novel high-performance organic semiconductors for various applications.

What potential applications may result from your research?

The most attractive potential applications from my research are highly efficient, low-cost, printable solar cells. Most commercial solar cells nowadays utilise either silicon or III-V group semiconductors and are the most expensive kind of renewable energy. Solar cells based on solution-processible organic materials can reduce the cost by several folds but the current efficiencies are still too low to compete with the ones on the market. It is expected that increased efficiencies can be achieved in my project.

What do you hope to achieve in your career?

I wish to start my career as either a postdoctoral research fellow or an R&D scientist in the chemical industry. Eventually, I wish to start my own company and make a difference in our world with my knowledge.

What is the benefit from undertaking a joint UoM and CSIRO project?

My UoM supervisors, Prof Ken Ghiggino and A/Prof Jonathan White are respectively experts in molecular physics and chemical synthesis; my CSIRO supervisor, Dr Scott Watkins is an expert in device engineering and fabrication. The joint supervision from UoM and CSIRO provides me with support in a diverse range of fields, and allows me having access to state-of-art facilities for both chemical synthesis and device fabrication.

What academic or personal achievement are you the most proud of?

I would say it's a combination of both an academic and a personal achievement; I met my wife by helping her to pass first year chemistry! I refer this to as a strategic application of knowledge.

What role do you think science has to play in society?

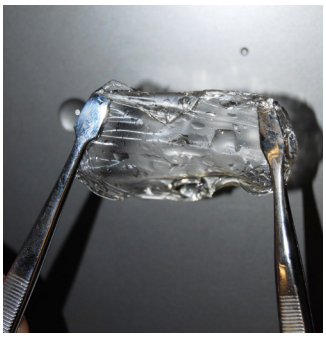
In modern society, an ever-increasing number of young people are moving away from science, which is of vital importance to a nation's economy, industry and innovation capability. I personally think that young students have to be exposed to science and given the opportunity to explore and appreciate its beauty. We must attract more students from future generations to pursue their study and career in science-related fields.

MMI research themes: overview

MMI's research is focused around four major themes, covering the breadth and depth of materials research: Nanomedicine, Materials for energy, Materials processing and Quantum technologies. Themes are led by academics from the Schools of Chemistry, Engineering and Physics.

Nanomedicine

Theme leader: Prof Frank Caruso, Dept of Chemical & Biomolecular Engineering.

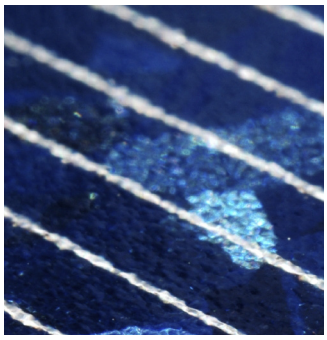


Ultrathin hydrogel film. (B.Ozcelik)

This theme explores the interface between biological and inorganic materials by synthesising nanotechnological drug delivery systems. It also aims to develop biomedical platforms for advanced tissue engineering.

Materials for energy

Theme leader: A/ Prof Rachel Caruso, School of Chemistry.

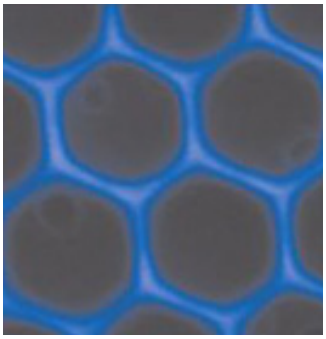


Extreme close-up of a Photovoltaic solar cell.

This theme explores new materials that enhance energy efficiency or provide more sustainable alternatives to existing technologies .

Materials processing

Theme leader: Prof Peter Scales, Dept of Chemical & Biomolecular Engineering.

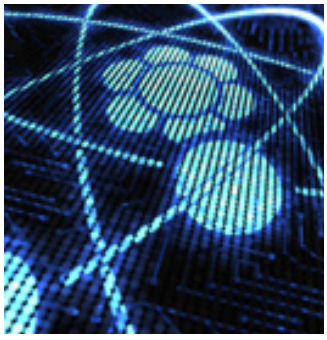


Extract of a presentation of a method for the preparation of photoresponsive, metal absorbing, and ordered porous materials. (L. A. Connal, G. V. Franks and G. G. Qiao)

This theme covers colloid and surface science, bioengineering, biomechanics and particle processing. It focuses on solving major biomedical, health and water challenges.

Quantum technologies

Theme leader: Prof Lloyd Hollenberg, School of Physics.



Artist's impression of an atom.

This theme exploits powerful and previously untapped principles of the quantum world to create novel materials and devices, such as quantum sensors capable of monitoring sub-cellular processes.

The lists of names of researchers, students and associated research centres appearing under each theme in the following pages are not exhaustive and only aim to be 'a snapshot' of the research done in the corresponding field at the University of Melbourne.

Nanomedicine 2011 highlights

Theme leader:
Prof Frank Caruso

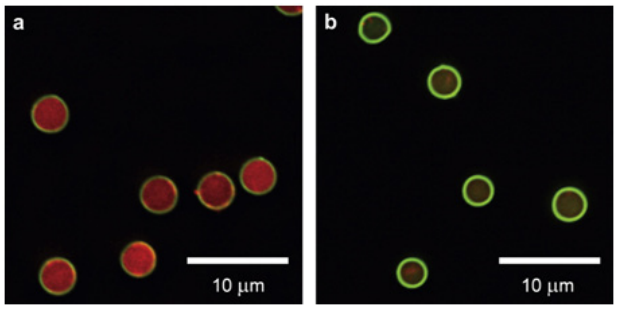
Researchers
Prof Frank Caruso, Prof Stephen Kent, Prof James McCluskey, Prof Paul Mulvaney, Prof Greg Qiao, Prof Robert Shepherd, Prof Geoff Stevens, A/Prof Muthupandian Ashokkumar, A/Prof Andrea O'Connor, Dr Jiwei Cui, Dr Kate Fox, Dr Kumar Ganesan, Dr David Garrett, Dr Angus Johnston, Dr Hirotaka Ejima, Dr Peck Ling Lee, Dr Carrie Newbold, Dr Clem Powell, Dr John Provis, Dr Rob de Rose, Dr Gabriel da Silva, Dr Georgina Such, Dr Damien Mertz, Dr Yajun Wang, Dr Yan Yan, Dr Zhiyuan Zhu, Dr Hannah Lomas, Dr Henk Dam, Ms Marloes Kamphius.

Associated research centres
Bio21 Institute, Particulate Fluids Processing Centre (PFPC).

First quantum measurement in living cell
A strong interdisciplinary collaboration among research teams led by Prof Hollenberg, Prof Caruso and Prof Mulvaney, demonstrated, for the first time, a quantum measurement in a living cell using nanodiamonds.

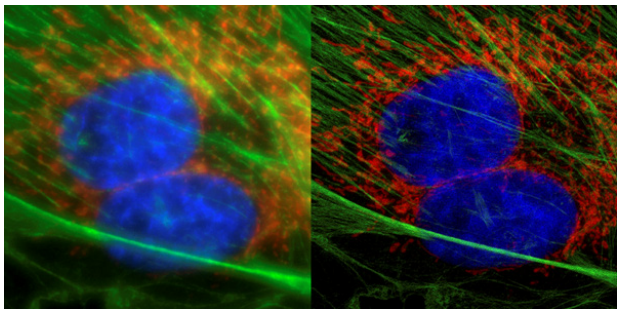
Smart materials
The research team led by Prof Caruso have also developed new 'smart' materials that can respond to changes in the cellular environment, that have low fouling properties, that self-assemble on surfaces and that have controlled degradation in the reducing environment of the cellular cytoplasm.

Multiple compartment compounds for improved drug retention
Loading and retaining low molecular weight compounds, such as anti-cancer drugs, is a significant challenge in nanomedical research. To this end Prof Caruso's group has incorporated multiple compartments such as liposomes and polymersomes to improve the retention of such drugs. The research team led by Prof Caruso have also demonstrated the loading, delivery and release of siRNA to prostate cancer cells.



Deconvolution microscopy images of DNA plasmid (red) encapsulated in nanoengineered polymer capsules (green). (S. Ng)

Super-resolution microscopy
Prof Caruso's team took delivery of a 'super-resolution' optical microscope, which has double the resolution of conventional microscopes. This instrument represents a quantum shift in cellular imaging. It will enable researchers to image sub-cellular compartments, in real time, and will shed new light on how nanomaterials are processed by cells.


Comparison of conventional microscopy (left) and super-resolution microscopy (right). The cell is stained so that the nucleus is blue, microtubules are green and the mitochondria are red. (A Johnston)

Materials for energy 2011 highlights

Theme leader
A/Prof Rachel Caruso

Researchers
Prof George Franks, Prof Ken Ghiggino, Prof Lloyd Hollenberg, Prof Andy Holmes, Prof Paul Mulvaney, Prof John Sader, Prof Kenong Xia, A/Prof Rachel Caruso, Dr Dehong Chen, A/Prof Ray Dagastine, Dr Liza Forbes, Dr David Jones, Dr Daniel McDonald, Dr Anthony Morfa, Dr Tich Lam Nguyen, Dr John-Paul O'Shea, Dr Carolina Tallon, Dr Xingzhan Wei, Dr Xiaolin Wu, Dr Wei Xu.

Associated research centres
Advanced Porous Materials Group, Nanoparticle.com, Photophysics Research Group, the Holmes Group.

Millimetre sized titanium/zirconium oxide beads with highly porous morphology have potential in the removal of radioactive elements from nuclear waste. (M. Chee Kimling)

Titania for dye-sensitised solar cells
Metal oxide materials with controlled nanoscale morphology have been fabricated using chemical approaches. Titania, in particular, has wide application including in dye-sensitised solar cells. The controlled structural properties of this material have led to enhanced effectiveness in the solar cell application. For example, the nanoparticulate entities that construct the materials have high surface areas that increase the quantity of dye that can be loaded in the electrode. In addition, the outer form of the material can be modified to increase light scattering within the electrode, thereby increasing the probability of light harvesting.

Titanium zirconium oxide beads functionalisation
Sol-gel chemistry has been used to prepare mixed titanium zirconium oxide beads, as mixing different metal oxides together allows for tailoring of material properties. These beads have higher surface areas than their single oxide counterparts, and remain amorphous at temperatures at which the single oxides crystallise. The potential for such materials to capture and contain radionuclides has been studied in collaboration with the Australian Nuclear Science and Technology Organisation. The materials can be functionalised to increase the number of binding groups and the pore structure of the material modified to alter adsorption rates.

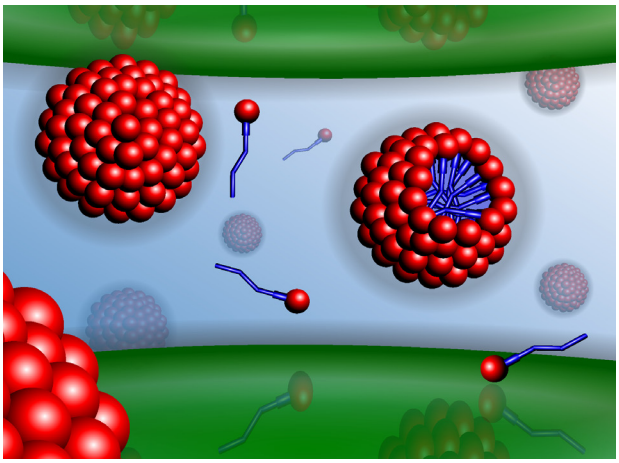
Materials processing 2011 highlights

Theme leader
Prof Peter Scales

Researchers
Prof Muthupandian Ashokkumar, Prof Frank Caruso, Prof Sandra Kentish, Prof George Franks, Prof Greg Qiao, Prof Peter Scales, Prof Geoff Stevens, Prof Richard Strugnell, Prof Kenong Xia, A/Prof Rachel Caruso, A/Prof Ray Dagastine, A/Prof Malcolm Davidson, A/Prof Michelle Gee, A/Prof Andrea O'Connor, Dr Gabriel Da Silva, Dr Kate Fox, Dr David Garrett, Dr Sally Gras, Dr Dalton Harvie, Dr Greg Martin, Dr John Provis, Dr Anthony Stickland.

Associated research centres
ARC Centre of Excellence in Design of Light Metals, Centre for Greenhouse Gas Technologies (CO2CRC), Particulate Fluids Processing Centre (PFPC), Defence Materials Technology Centre (DMTC).

Engineered products
Significant scientific advances have been made in the development of engineered material products, positioning them for more rapid implementation. New analytical techniques using synchrotron and neutron beam-line facilities, have been developed, enabling the research team to characterise the extremely complex disordered structure of cements and geopolymers. These techniques, combined with multi-scale mathematical modelling, have provided the first detailed description of the process of geo-polymer formation at an atomic level. Better understanding of how to control the amount and morphology of porosity in advanced ceramic materials has been gained. These ceramic foams have application in diverse areas, such as ultra high temperature insulation and bone tissue scaffolds. Studies of fracture of titanium alloys and development of novel bronze alloys provide new materials for defence aerospace and naval applications. In the area of dairy processing, investigations of cheese microstructure lead to improved production techniques. Synthesis of novel architecturally complex macromolecules afford materials for advanced automotive and industrial coatings.



Self-assembled surfactant micelles trapped between emulsion droplets induce history-dependent forces that can reversibly stick drops together. (R. Tabor, R. Dagastine, F. Grieser, D. Chan)

Material separations
Experimental measurements and molecular simulations of high temperature gas adsorption onto nanoporous carbon elucidate new approaches to separating and sequestering CO_2 green house gas. Pilot scale facilities in Hazelwood power station (Victoria) provide a platform for validation of the work on large scale. The influence of polymer architecture on the dewatering performance of temperature-responsive flocculants has been useful in designing flocculants that can more easily be incorporated into typical mineral processing schemes and reduce the cost of pumping mineral tailings. Modelling, validated by experiment, gives insight into improved methods of operating vacuum filtration devices for solid-liquid separations. Fundamental studies of the binding of metal ions to organic complexing agents enables the design of extractants used to remove heavy metal contaminants from waste water streams.

Interfacial phenomena
The study of interfacial phenomena underpins materials processing in different application areas. Foodstuffs, consumer products, mineral processing, ceramics armor, rocket leading edges and wastewater treatment all depend on the understanding of molecules at interfaces on the nanoscale. Much progress has been made in understanding repulsive van der Waals forces, bubble coalescence and the role of structural forces in deformable interfaces. The combination of mathematical modelling and atomic force microscopy has enabled rapid advances in the area.

Quantum technologies 2011 highlights

Theme leader
Prof Lloyd Hollenberg

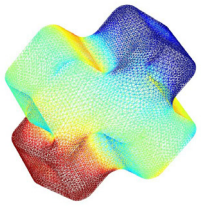
Researchers
Prof Frank Caruso, Prof David Jamieson, Prof Fedor Jelezko (University of Ulm, Germany), Prof Paul Mulvaney, Prof Steven Prawer, Prof Jorg Wrachtrup (University of Stuttgart, Germany), A/Prof Andy Greentree, A/Prof Jeffrey McCallum, A/Prof Ann Roberts, A/Prof Robert Scholten, Dr Andrew Alves, Dr Alberto Cimmino, Dr Brant Gibson, Dr Daniel Gomez, Dr Charles Hill, Dr Angus Johnson, Dr Stefan Kaufman, Dr David Simpson, Dr Paul Gregory Spizzirri, Dr Laurens Willems Van Beveren, Dr Yan Yan, Dr Changyi Yang.

Associated research centres
Bio21 Institute, Centre for Coherent X-ray Science, Centre for Nanoscience and Nanotechnology, Centre for Quantum Computation and Communication Technology, Micro-Analytical Research Centre (MARC).

Quantum decoherence detecting
In a collaboration between groups from the Schools of Chemistry and Physics, researchers L. McGuinness (PhD student) and D. Simpson conducted a series of experiments where nanodiamonds were immersed in a spin-rich solution of manganese ions. The quantum decoherence of individual nitrogen-vacancy defects in the nanodiamonds was used to detect the diffusion and accretion of manganese ions onto the diamond surface. These experiments prove the feasibility of using quantum decoherence of the nitrogen-vacancy probe to detect processes at an atomic level in ambient aqueous conditions. This work follows the completion of the ground-breaking quantum measurements of nanodiamonds in a living cell by the same collaboration, published in Nature Nanotechnology.

Nanophotonic materials
In collaboration with CSIRO, researchers in the School of Physics are investigating the potential of nanometric optical antennas to control the emission of light by fluorescent molecules and other emitters. They are also looking to incorporate active elements, such as quantum dots, to introduce gain into plasmonic devices with a view to producing a nanoscale modulator. The potential applications emerging from this research program range from new light sources for communications, high-sensitivity detectors, biological and chemical sensing and optical computing.

Ion implantation for optical devices and graphene transistors
Ion implantation is being investigated as a pathway for formation of silicon nanocrystal (Si-nc) sensitised erbium (Er) doped silicon/silicon-dioxide slot waveguide structures. These structures, in which light is confined to a nanometre-scale low-index region between two high-index regions, potentially offer significant advantages for realisation of electrically-pumped silicon devices with optical gain and potentially quantum optical devices. The team is currently investigating an alternative pathway in which high quality thermal oxides are grown on silicon and ion implantation is used to introduce the Er and Si-ncs into the SiO_2 layer. This approach provides considerable control over the Er and Si-nc concentrations and depth profiles, which is important for exploring the available parameter space and developing optimised structures. The use of ion implantation is also being explored for the fabrication of high quality large area graphene layers on thin metal layers on semiconductor substrates as a pathway to graphene field-effect transistors.



Modelled surface charge distribution on a cross-shaped silver nanoparticle of arm length 120 nm. (A. Roberts)

Nanowire-based devices
Semiconductor nanowires offer the possibility to fabricate nanoscale devices that exhibit enhanced functionality compared to conventional device structures, opening up new opportunities in fields including electronics, quantum computing, optoelectronics and sensing. A recently installed cryogen-free dilution refrigerator in the School of Physics will allow researchers to spectroscopically investigate nanowire-based devices, revealing the fundamental quantum mechanical structure responsible for their unique properties. Understanding these novel semiconductor devices at a fundamental level will reveal the factors that control electronic transport in these structures and how they can best be tailored to be exploited in a broad range of optical, electronic and sensing applications, opening up the opportunity for new commercial device development and further research.

Interdisciplinary Seed Funding scheme

This scheme, run centrally by the Office of the Deputy Vice-Chancellor (Research) - DVC(R) - and the Melbourne Research Institutes, provides funding to address complex problems facing society with solutions that demand an interdisciplinary approach. The scheme seeks to support research activities that:

- will benefit from short-term seed funding;
- will lead to new interdisciplinary collaborations;
- can identify strong opportunities for external funding; and
- are consistent with the broad research objectives of one or more of the Melbourne Research Institutes or designated emerging areas of focus.

The MMI supported twelve projects commencing in 2011 in a range of areas:

1. Bacteria: living sponges for waste water purification
2. Cell mechanobiology approach to understanding degenerative changes in osteoarthritis
3. Engineering the removal of asbestos fibres from the lung
4. Metal nanowire metamaterials from anodic aluminium oxide nanotemplates: towards a practical 'invisibility cloak'
5. Nanolens arrays for sensitive high-resolution fluorescence microscopy
6. Novel hybrid diamond-metal oxides for advanced electro-optic applications
7. Painting with radical dots
8. 'STAR' nanobombs for targeted and effective cancer eradication
9. Strengthening titania nanoparticle networks by room temperature chemical sintering for flexible dye-sensitised solar cells on plastic substrates.
10. Synthetic mimics for bio-film adhesion: unifying concepts on a molecular scale
11. 'Theragnosticnanodiamonds': fluorescent biomarkers for quantum sensing and therapeutic delivery in living cells
12. Wireless strain gauges for implant dentistry: towards the bionic bone sensor.

Bacteria: living sponges for waste water purification

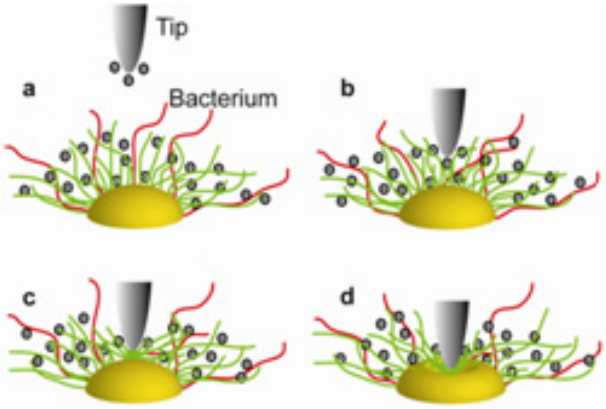
Investigators: A/Prof Michelle Gee, School of Chemistry; Dr Huabin Wang, School of Chemistry; Prof Richard Strugnell, Dept of Microbiology and Immunology; Prof Spas Kolev, School of Chemistry.

Purpose

Waste water from industries such as mining is a serious environmental problem. It can contain toxic and carcinogenic heavy metal ions such as lead, zinc, arsenic or copper ions and often ends up in soil and contaminates ground water. Even domestic water with high concentrations of calcium or magnesium (hard water) leads to over consumption of household detergents that pollute our waterways. For both water conservation and pollution control it is important to collect and remove heavy metal toxins from waste water so that water can be safely reused or returned to the environment.

Recent work has shown the potential of naturally occurring polysaccharides to absorb heavy metals; a process called biosorption. These types of polymers are produced naturally by bacteria to form a 'capsule' that envelopes the cell. The capsule is a complex living polymeric material, able to adapt as a bacterium responds to changes in its environment.

The aim of this project is to engineer the bacterial polysaccharide capsule for ion adsorption. This will enable the development of bacterial colonies as living ion sponges for the removal of heavy metal toxins from waste water – a cheap and green alternative to current water purification methods. The team will do this by exploiting a new, broad-spectrum mechanism for heavy metal uptake.



Progress

To date, the team has developed a nanomechanical model of bacterial cell compression (see Figure 1). This model allows to perform nanoindentation contact mechanics experiments on live bacteria, from which researchers can extract molecular level information on the organisation of the bacterial capsule and cell cytoplasmic turgor. The nanomechanics experiments have yielded the first quantitative measure of the bacterial capsule under physiologically relevant conditions. By using capsule-deficient mutants as a control set, researchers have also shown for the first time that the capsule adapts when a bacterial cell is stressed osmotically and will absorb ions. This mechanism protects the cell so that it remains viable (see Figure 2). These findings constitute a major step forwards in the development of bacteria as broad-spectrum ion sponges for wastewater purification.

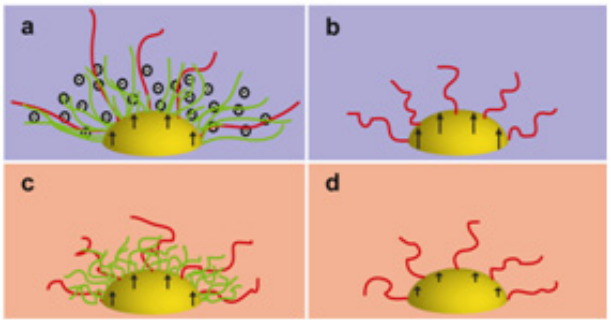


Fig. 2 (above): Schematic illustrations comparing the responses to compression of wild-type and capsule-deficient bacterial cells in pure water (mauve background, a and b, respectively) and in 100mM $CaCl_2$ solution (pale orange background, c and d, respectively). (M. Gee)

Fig.1 (left): Schematic representation of the mechanical model for bacterial cell compression by an AFM tip. Capsule polysaccharides are represented by the green lines bearing charged groups. (M. Gee)

Cell mechanobiology approach to understanding degenerative changes in osteoarthritis

Investigators: A/Prof Peter Vee Sin Lee, Dept of Mechanical Engineering; Dr Nicole Walsh, St Vincent's Institute; A/Prof Andrea O'Connor, Dept of Chemical and Biomolecular Engineering.

Purpose

Osteoarthritis (OA) affects 1.62 million Australians and imposes a significant burden on healthcare expenditure. OA is characterised by loss of joint articular cartilage (AC). Affected patients suffer significant pain and disability.

The primary cells within the AC are the chondrocytes and these cells are responsible for the maintenance of the extracellular matrix (ECM), which is the main weight bearing component in AC. An imbalance in the activities of the chondrocytes could lead to ECM degradation, hence AC breakdown.

In addition, the activities of the AC chondrocytes are closely regulated by the mechanical forces applied to the cells. Therefore, any change to the mechanical properties of chondrocytes (e.g. stiffness) would have a significant effect on how chondrocytes sense physical forces in the AC environment. Any attempt to halt the progression of post-traumatic OA will require a quantitative answer to the question: can the mechanical properties of chondrocytes be altered by abnormal joint loads?

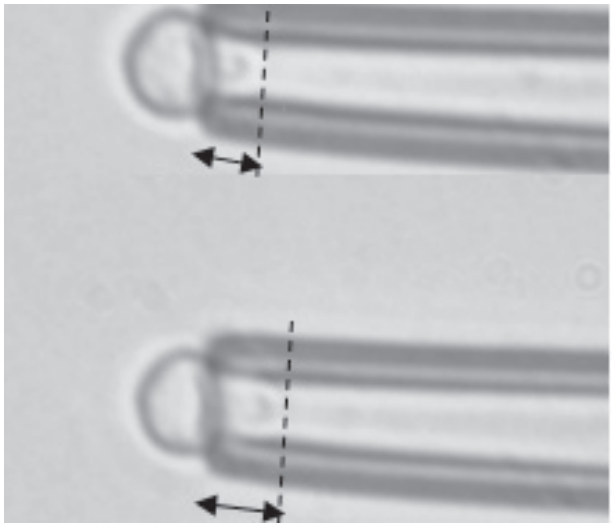
In this study, chondrocytes biomechanical properties will be investigated following abnormal joint loads using the micropipette aspiration technique. This technique applies a controlled suction pressure to the surface of a single cell and tracks its deformation to compute the mechanical properties or stiffness of the cell.

Micropipette aspiration of porcine cartilage cell: the stiffness of the cell was measured by progressively aspirating the cells into the micropipette. (P. Lee)

Progress

Porcine cartilage from the knee joint was impacted using an instrumented drop tower to simulate injurious loading to the knee joint. After impact, the cartilage cells (chondrocytes) were isolated at different time points for micropipette aspiration. Real time images of the aspirated cell or cell elongation in the micropipette were recorded in order to obtain the Young's modulus or stiffness of the cell. The team found that the impacted chondrocytes recorded a higher stiffness value when compared to the non-impacted chondrocytes. The change in the stiffness of the cell may influence its ability to sense physical forces in the cartilage environment and to maintain the overall health of the cartilage.

Further micropipette aspiration tests are being conducted on chondrocytes from a mouse model, with destabilised joints with cartilage similar to that in an osteoarthritic joint. The chondrocytes are currently being isolated and tested at 1 week, 4 week and 8 week time points to track the relationship between cartilage degeneration and the corresponding cell stiffness, in order to further understand the cell's ability to maintain cartilage health.



Engineering the removal of asbestos fibres from the lung

Investigators: Dr John Provis, Dept of Chemical and Biomolecular Engineering; Dr Yan Yan, Dept of Chemical and Biomolecular Engineering.

Purpose

The toxicology of nanomaterials – and particularly inorganic nanomaterials – is an emerging research focus on an international scale, and one which fundamentally requires an interdisciplinary approach, involving nanomedicine and materials processing expertise. The need for thorough investigation of nanoparticle toxicology is particularly demonstrated by the known detrimental long-term effects of many naturally occurring nanomaterials such as asbestos.

Australia has one of the highest rates of asbestos-related disease in the developed world, and the societal and financial importance of preventative treatments for asbestos-exposed patients should not be underestimated.

This project has worked to develop methods and chemical models for the dissolution of key asbestos minerals, with possible implications for the study of cytotoxic effects of natural and engineered nanoparticles. The team has focused on dissolution in simulated lung fluid as a system to represent the process of asbestos clearance from the human lung, and has tested a variety of small organic chelating agents for efficacy in enhancing the dissolution of asbestos-forming minerals under these conditions.

In particular, the researchers have applied for the first time techniques adopted from the fields of chemical reaction engineering and minerals processing to the question: is it possible to use non-toxic chelating agents to accelerate the clearance of asbestos fibres from human lungs?

Progress

This project was provided with funding to support approximately 50% of a Research Assistant (RA) position for a nine month period. During this time, the team was able to collect data related to the dissolution behavior of amphibole minerals - which are potentially the most hazardous of all asbestos-forming minerals when taking on a fibrous crystal habit - in simulated lung fluid, in the presence of a number of small organic chelating agents.

Each of the different chelating agents tested (oxalate, acetate, citrate and EDTA) showed some small extent of enhancement of the dissolution process of amphibole minerals; the most effective was probably either oxalate or EDTA. None of the molecules showed overwhelmingly rapid acceleration of the dissolution of the amphibole mineral under the laboratory test conditions. However, each molecule showed selectivity towards specific components of the amphibole mineral.

This may lead to interesting opportunities for future tailoring of accelerated-clearance agents, if the specific mineralogy of the amphibole to which a patient has been exposed can be determined. The team has also conducted a detailed literature review in this area, through the work of the RA and also a final year research project student, and the results of both the literature review and experimental study are currently being prepared for publication.

Asbestos (tremolite) silky fibres on muscovite from Bernera, Inverness-shire. Photograph taken at the Natural History Museum, London. (Aram Dulyan)

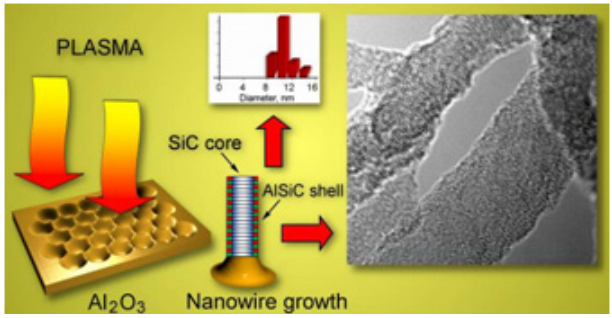
Metal nanowire metamaterials from anodic aluminum oxide nanotemplates: towards a practical 'invisibility cloak'

Investigators: Ms Jinghua Fang, School of Physics; A/Prof Ann Roberts, School of Physics; Prof Paul Mulvaney, School of Chemistry/Bio21 Institute.

Purpose

The invisibility cloak is a concept that is leaping from science fiction to reality. Current proposals for cloaking materials rely on the control of light via metamaterials – media with designed permabilities and permitivities that allow sophisticated control of the propagation of light through the material. Such control allows for the bending of light around regions of the material with a phase shift equivalent to that seen in free space – quite literally producing an invisibility cloak. Such cloaks are expected to be extremely useful in defence applications and represent an entirely new class of optical materials. Although cloaks have been demonstrated in the microwave spectrum, there are few demonstrations in the visible regime due to the difficulties of fabricating the required circuit elements.

In this project, the research team proposes to use arrays of silver nanowires, formed by the anodic aluminium oxide (AAO) template process. Related theoretical predictions show that such a structure should exhibit negative refractive index, and therefore offers a cheap, efficient and experimentally realisable cloak. This seed grant will enable the team to perform proof-of-concept experiments to prepare for ARC submission, and to secure pertinent IP for possible commercialisation.



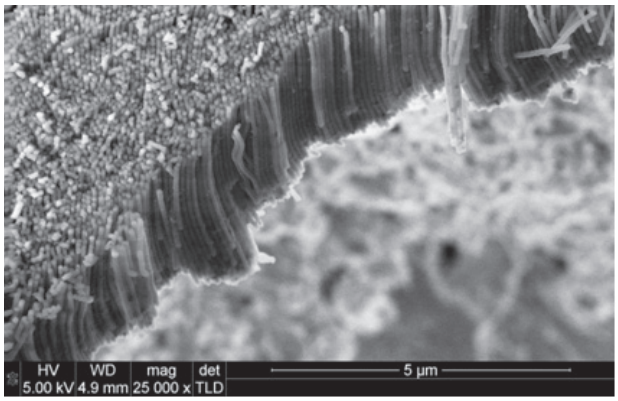
Above: Catalyst-free synthesis of the core-shell, ultra-thin, size-uniform SiC/AlSiC nanowires on a periodic anodic aluminum oxide template (J.Fang) . Right: High quality silver nanowires annealed at high temperature. (J Fang)

Progress

A collaboration has been established with the Optics group (UoM) and CSIRO Materials Science & Engineering (MSE) division. This has enabled researcher Jinghua Fang to perform lithography using negative and positive resists and to build patterns for the fabrication of curved AAO templates of different aspect ratios. The team successfully fabricated an AAO template displaying a hexagonal pore array pattern, whose pitch size ranges from a few micrometers to tens of micrometers.

With the help of the CSIRO MSE division plasma nanoscience group, Ms Fang has mastered the ion milling system, high quality sputtering coating system, ICP-CVD system, AFM and UV-visible spectrometer. These facilities provide additional techniques for tailoring AAO templates and related metamaterial fabrications. The team was granted permission to use the CSIRO's SEM/FIB, which provides higher resolution than normal SEM and enables tailoring of the sample at the microscale.

The team has set up the experimental framework for the project and built a wide collaborative network of researchers from other Schools and Faculties, the Bio21 Institute and CSIRO. The team's work currently involves a PhD student, whose skills in electrodeposition are used to fabricate silver nanowire arrays. The team aims to attract more PhD students and include more researchers to this project, including international collaborators at the University of Cambridge.



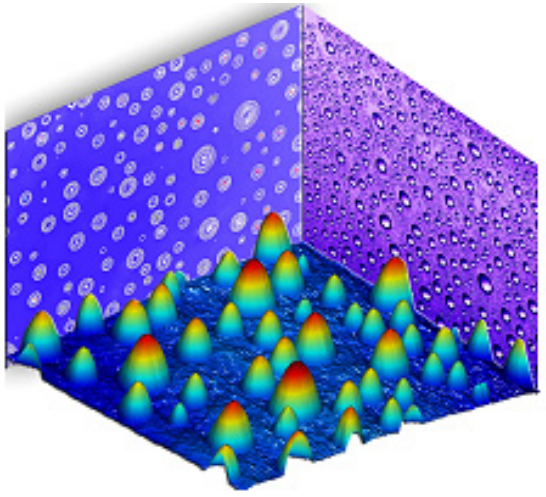
Nanolens arrays for sensitive high-resolution fluorescence microscopy

Investigators: A/Prof Trevor Smith, School of Chemistry; Prof Greg Qiao, Dept of Chemical and Biomolecular Engineering; Dr Xiaotao Hao, School of Chemistry; Dr Xuehua Zhang, Dept of Chemical and Biomolecular Engineering.

Purpose

Fluorescence microscopy technologies with resolution beyond the diffraction limit are required in a diverse range of disciplines including nanomedicine and cell biology (investigating the structure and function of cells), and photovoltaic materials research (where the homogeneity of films influences the efficiency of device performance). Several new imaging technologies have been developed recently, which are based on tailored illumination, nonlinear fluorophore responses, or the precise localisation of single molecules. All of these techniques are, however, either time-consuming or require high laser intensity for collecting images, which consequently incur drawbacks like sample movement and photobleaching. Alternative approaches are therefore highly sought-after.

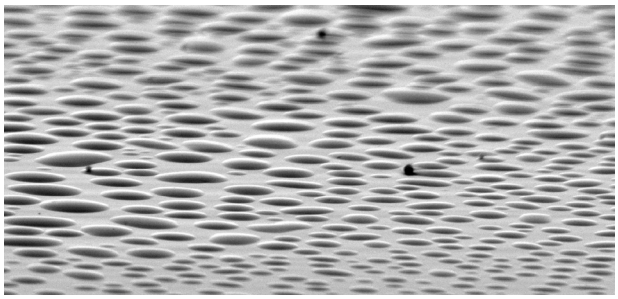
This project aims to produce well-defined patterned nanolens arrays with tailored material and optical properties and investigate the potential of these arrays to provide high resolution optical microscopy of biological and polymeric materials.



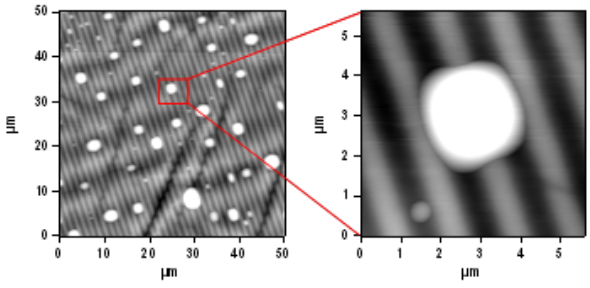
From nanodroplets (rear right) to polymeric nano-lenses (front, 3D image). The Newton rings were generated by nanolenses (rear left). (X. Zhang et al.)

Progress

Spherical nanolenses with heterogeneous sizes and random distribution have been successfully fabricated on a hydrophobic glass surface. The imaging, near-field focusing and magnification behaviours of spherical nanolenses have been analysed. Uniform droplets were formed by direct adsorption from emulsion or slowing down the nucleation process during formation of nanodroplets. The team has attempted to design and control the arrangement of the nanolenses on the surface by forming droplets on surfaces pre-patterned by soft lithography. In addition, the patterned colloidal crystals are currently under preparation for coherent diffraction X-ray imaging.



SEM images of nanolenses prepared by in-situ polymerization. (X. Zhang et al, Soft Matter)



Nanolenses fabricated on patterned surface. (T. Smith)

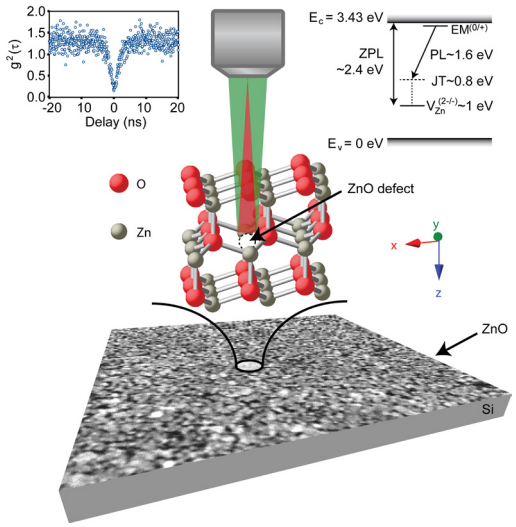
Novel hybrid diamond-metal oxides for advanced electro-optic applications

Investigators: Dr Snjezana Tomljenovic-Hanic, School of Physics; Dr Brant Gibson, School of Physics; Dr Stefania Castelletto, School of Physics; A/Prof Andrew Greentree, School of Physics; Dr Anthony Morfa, School of Chemistry/Bio21 Institute; Dr Matthias Karg, School of Chemistry/Bio21 Institute.

Purpose

This project combines the modification and characterisation of diamond (Physics) and the extensive materials synthesis, fabrication and characterisation of metal oxide thin-films (Bio21Institute). While there has been extensive research determining how diamond can be used for quantum information applications, new approaches are needed to utilise this remarkable material in a simple and reliable manner. Zinc oxide (ZnO) has been investigated for many years due to its optical transparency in the visible and its high conductivity. Yet, the well-known defect luminescence has never been studied on a single-defect level, leading to rampant speculation on its origin.

Building on recent work in materials science, this project aims to combine the extraordinary properties of optical centres in diamond with the simple to fabricate, solution-processed metal oxides. A host of metal oxide materials can be made, using either sol-gel or nanoparticle ink routes. This project focuses on embedding diamond in a zinc oxide host which can be lithographically altered to produce optical elements that will enhance future applications of diamond.



Progress

Two important outcomes have been achieved in this project. Firstly, the complete optical and quantum characterisation, of the host material, ZnO, has been completed. Secondly, successful incorporation of diamond in ZnO and the effect of post processing the optical properties of diamond have been determined.

Optical emission from single, isolated zinc vacancies in ZnO has been observed and characterised for the first time. This work opens a door to explore a new material for single photon development, and simultaneously allows the quantum characterisation techniques developed for quantum emitters to be applied to ZnO for the first time. These results identify a new source of single photons in a readily available wide band gap semiconductor material which has exceptional electrical, optical, and biocompatibility properties. This work is of interest to many scientists including materials scientists interested in single defects, and quantum and optical scientists who can harness single photons for a number of quantum information processing technologies. This work was published in Nano Letters.

The optical and quantum characterization of ZnO was critical in this project, as it clearly differentiates the properties of ZnO from diamond and provides a clear optical method for studying and minimising defect densities in ZnO. With control of ZnO defects, and a new method for observing them, diamond was successfully included in ZnO inks and solution processed to form thin solid films. The optical properties of the diamond and ZnO were studied after different post processing methods. Zinc oxide has been found to be an excellent host for diamond. New applications are being explored for this new hybrid material, including electronic and optical control of diamond emission.

Artists' impression of single defects in the zinc oxide host being probed using optical microscopy. The resulting data (top left) confirms single-defect emission from the proposed zinc vacancy (energy diagram shown top right). (B. Gibson, A. Morfa)

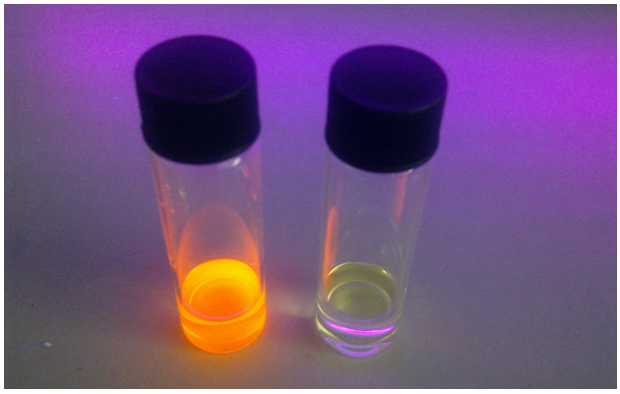
Painting with radical dots

Investigators: Prof Carl Schiesser, School of Chemistry; A/Prof Robyn Sloggett, Historical Studies; Prof Paul Mulvaney, School of Chemistry.

Purpose

The 20th century saw revolutionary art practices driven in part by technological developments in the production of art materials and the availability of new industrial materials. Artists enthusiastically embraced these new materials in ways that radically changed art process and practice. Choices offered by traditional pigments and media were extended with synthetic media, new pigments and dyes, and additives that modified paint handling and performance. Given the cultural significance of many works of art and their inherent value, it is important that conservators have a firm understanding of the performance characteristics of the media used during their creation in order to provide advice in relation to the optimum environment for housing, to ensure longevity, and to inform future conservation practice.

It is well established that cell damage associated with numerous diseases can be brought on by radicals and related reactive oxygen species (ROS), often through exposure to pollution or UV radiation. ROS also cause the deterioration of plastics, the fading of paint and the degradation of works of art. This project aims to develop new technology to explore free radicals and oxidative stress in artists' materials in order to provide new fundamental insight into their long-term performance.



Intense fluorescence of a solution of 4.7 nm CdSeCdS (core/shell) quantum dots (left), quenched by nitroxide free radicals (right). (Tich Lam Nguyen)

Progress

Quantum dots (QD) are fluorescent semiconductor nanoparticles whose wavelength of fluorescence is dependent on their size and shape. High photostability makes QDs superior to organic fluorophores for long-term applications.

Tethering a stable free radical - such as a nitroxide - to a QD results in a stable profluorescent species and the loss of fluorescence. In situations of oxidative stress or in the presence of free radicals, there is a quenching of the doublet state of the nitroxide, such that fluorescence is reactivated. This combination of the properties of stable nitroxide radicals and quantum dots will provide wavelength tuneable probes for free radicals and oxidative stress.

High quality, single crystal, monodispersed QD were prepared. These QDs were also stabilised through the subsequent overcoating with one or more homogeneous shell of a second semiconductor. These passivated core/shell QDs exhibit superior quantum yields (fluorescence emission efficacy) and are less likely to undergo side reactions in solution.

The team has shown that the intense fluorescence of green cadmium selenide (CdSe) QDs, prepared as above, is significantly quenched by the addition of only one equivalent of the stable free radical. This degree of QD fluorescence quenching by a stoichiometric quantity of radicals has not been reported previously. Importantly, researchers have also demonstrated that red CdSeCdCdSCdS core/shell QDs are also significantly quenched by the addition of three equivalents of the stable free radical. Importantly, when the radical centre in the quenched QD is removed with a reducing agent, the fluorescence is restored.

These results are particularly exciting because they demonstrate for the first time that the fluorescence of passivated core/shell QDs can be controlled through radical chemistry. In separate experiments, these passivated QDs proved to be unaffected by prolonged exposure to UV light, which makes them promising candidates for inclusion in paint.

‘STAR’ nanobombs for targeted and effective cancer eradication

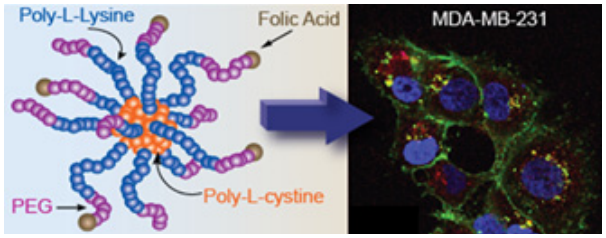
Investigators: Prof Greg Qiao, Dept of Chemical and Biomolecular Engineering; Dr Wei Duan, School of Medicine (Deakin University); Dr Anton Blencowe, Dept of Chemical and Biomolecular Engineering; Dr Paul Gurr, Dept of Chemical and Biomolecular Engineering.

Purpose

Worldwide, cancer is a leading cause of death, accounting for 13% of total deaths in 2004 (WHO report). Principle treatments, radiotherapy and non-targeted chemotherapy use a broad attack on cells, both healthy and cancerous, and thus are associated with serious side effects. Furthermore, chemotherapy only targets the bulk of the cancer cells, leaving the so-called cancer stem cells (CSCs) (a.k.a. the “root of cancer”) untouched. These cancer roots escape the therapy and can regenerate into a new cancer mass, leading to a patient’s relapse.

In this project, the team aims to develop a drug delivery system that can actively target and destroy these CSCs. Current research has been focused on directed chemotherapy and drug delivery approaches, which avoid damage to healthy cells. However, they do not specifically target the CSCs. Therefore, in order to achieve the active CSC targeting, ‘STAR’ nanobombs will be synthesised as targeted drug delivery vehicles, which possess the following characteristics:

(i) Stealth layer and size regime which can increase their circulation in the bloodstream;
(ii) Targeting RNA aptamer (oligonucleotide) which specifically target CSCs;
(iii) Acid-sensitive drug conjugated linkers which undergo rapid ‘bomb-like’ release of payload triggered by endosomal pH (5.5-6.5) and simultaneous protonation;
(iv) Rupture and release of protonated nanobombs disrupts endosome membrane flooding the cytoplasm with a lethal dose of cytotoxic drug (‘bombardment’), saturating the protein efflux pumps responsible for transporting the anticancer drugs out of the CSCs.



Progress

Amino acid-based core cross-linked star (CCS) polymers with poly(L-lysine) arms and poly(L-cystine) core have been synthesised. The CCS polymers possess hierarchical functionalities, spanning from the core, along the arms and at the periphery, and allow for facile post-polymerisation functionalisation (addition of functional groups). The allyl groups (C_3H_5) around the periphery were used for attachment of model targeting agent (folic acid) for cancerous cells. Subsequent *in vitro* study of the CCS polymers with breast cancer cell MDA-MB-231 revealed high cellular uptake, as confirmed by confocal microscopy and flow cytometry.

Cytotoxicity studies indicate that the CCS polymers (without drugs) are non-toxic to these breast cancer cells at concentrations up to 50mg/ml. Moreover, the disulfide bonds that made up the core structure of the stars could be cleaved easily under reducing condition, which render the stars (bio)degradable. The model study indicates that the resulting CCS polymer can act as a drug delivery carrier having targeting capabilities. The conjugation of targeting aptamers (that target receptors on cells) onto free drugs has shown improved selectivity towards CSCs. Therefore, combination of the CCS polymer and aptamer technologies, along with drug conjugation will yield STAR nanobombs capable of delivering and rapidly releasing their payloads in the CSCs, ultimately killing them.

This novel amino-acid based star polymer has opened up a new platform for polymer therapeutic applications, especially in the area of targeted drug delivery for cancer treatment, where biodegradability and biocompatibility are often the limiting factors.

Amino-acid based star polymers having polylysine arms and polycystine core, which have PEG layers and folic acid as targeting agent that promotes cellular uptake by MDA-MB-231 breast cancer cells. (A. Sulistio)

Strengthening titania nanoparticle networks by room temperature chemical sintering for flexible dye-sensitised solar cells on plastic substrates

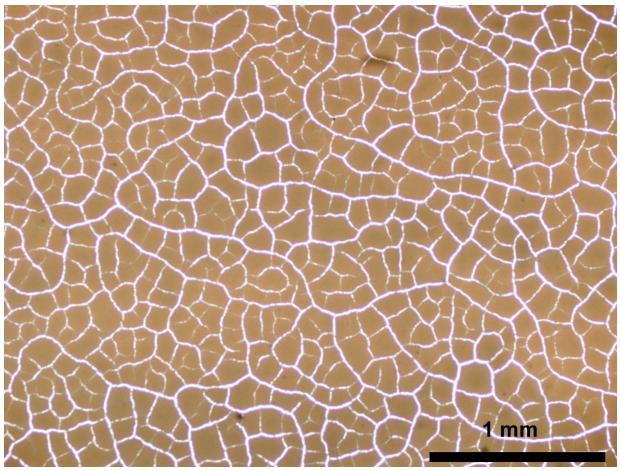
Investigators: Prof George Franks, Dept of Chemical and Biomolecular Engineering; A/Prof Rachel Caruso, School of Chemistry; Prof Yi-Bing Cheng, Materials Engineering, Monash University.

Purpose

The fabrication of high efficiency flexible dye-sensitised solar cells (DSSCs) requires novel approaches to enhance interconnectivity within the titania particle network. This must be conducted at temperatures below the softening point of the polymer substrates; for minimal cost (or energy consumption), room temperature is preferred.

Recently, chemical sintering has been enabled by the addition of water (about 20 to 30%) or acid (about 0.05M) to ethanol slurries, to improve strength and electrical connectivity of the titania nanoparticle networks. This has resulted in improved solar cell performance.

The research conducted within this project has investigated the precipitation of different types of inorganic semiconducting materials on to the contact points of the nano-particles. The aim has been to strengthen the nanoparticle network by enhancing the strength of bonds between individual particles.



Optical micrograph of titania nano-particle dry thin film showing the macroscopic mud cracks when processed from low volume fraction solids suspensions. (S. Tanurdjaja, X. Zhang, G. V. Franks)

Progress

Observation of the dried thin film of titania nano-particle networks has indicated that there are typically macroscopic (millimetre scale) mud cracks in the thin films (see figure).

The use of dissolvable or soluble inorganic additives such as TiN (to form TiO_2) or ZnO have not been found to be especially useful in preventing the macroscopic cracks observed in the dry thin film nanoparticle networks.

The cracking phenomena is caused by the large volumetric shrinkage when the low volume fraction solids titania nano-particle suspensions dry and consolidate. The shrinkage is constrained by the substrate which results in biaxial tensile stresses in the film and thus cracking.

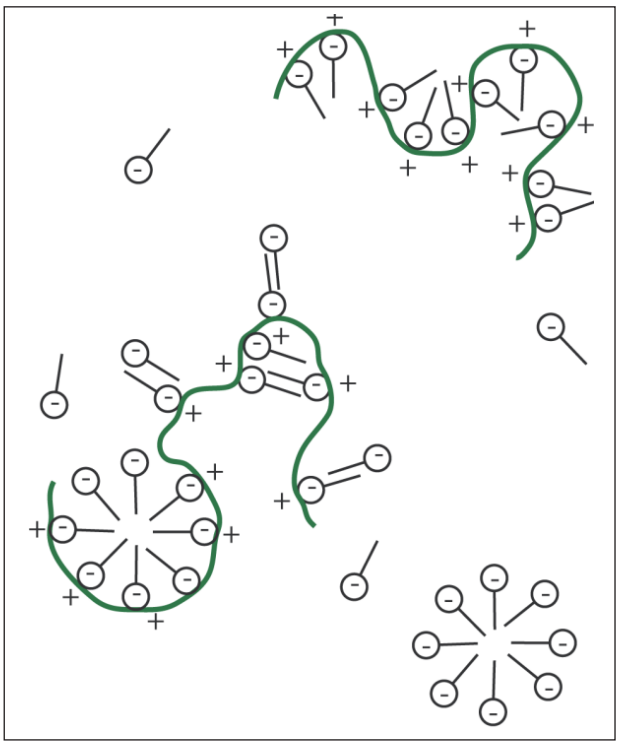
Thin films on flexible polymer substrates produced from larger size alumina particles (micrometer-sized) has resulted in crack-free thin films due to the higher achievable solids content in the suspension of the larger particles, compared to the titania nanoparticles.

Synthetic mimics for bio-film adhesion: unifying concepts on a molecular scale

Investigators: A/Prof Ray Dagastine, Dept of Chemical and Biomolecular Engineering; Dr Richard Wetherbee, School of Botany.

Purpose

Resolving the mysteries of polymer physics for both synthetic and biological polymers has led to amazing leaps in our understanding by literally, physically unraveling these polymers. This project employs the approaches developed to probe the origins of the strength of spider silk and bio-adhesives, to discover new insights into the molecular structure and function of polymer–surfactant complexes. Previously, the research team has focused on biological polymers in bio-film formation. This project focuses polymer–surfactant complexes as an approach to better understand bio-film formation through links to these unique synthetic systems with similar adhesive behaviours.



Polymer surfactant complexes in solution. (R. Dagastine)

Progress

Progress has focused on using an atomic force microscope to manipulate and unravel individual polymer-surfactant complexes using synthetic systems. Atomic force microscopy is developed to image and manipulate matter on the nanoscale efficiently, using touch. In this work, a thin metallic cantilever with a fine point -10 to 40 nm in radius - is used to attach to an individual polymer chain immobilised on a surface and is then slowly unfolded by pulling the cantilever away from the surface.

Polymer conformations have been explored through this method previously, whereas in this project, this approach has been used to examine how a polymer-surfactant system unfolds. Surfactants (e.g. soap molecules) aggregate to form micelles in solution. These micelles also bind to certain types of polymers and have a range of applications in personal care and food products. The team has unravelled a non-ionic polymer at a range of surfactant conditions.

Results suggest the polymer wraps around the micelles bound to the polymer. The team has mapped out the surfactant concentration ranges where this occurs. At low concentrations, there is insufficient polymer and at high enough concentrations, the micelles solubilise the polymer and it desorbs from the surface. In the intermediate range, the force data suggest that polymer behaves similarly to a modular protein. This may be related to larger macroscopic adhesion behaviour seen in polymer-surfactant complexes.

‘Theragnostic’ nanodiamonds: fluorescent biomarkers for quantum sensing and therapeutic delivery in living cells

Investigators: Dr David Simpson, School of Physics; Dr Yan Yan, Dept of Chemical and Biomolecular Engineering; Dr Angus Johnston, Dept of Chemical and Biomolecular Engineering; Dr Brant Gibson, School of Physics.

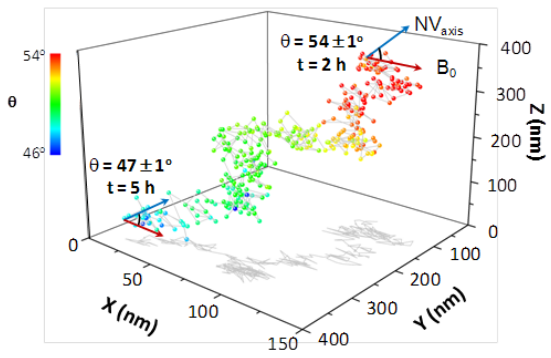
Purpose

Nanotechnology flags revolutionary advances in the development of new therapeutic and diagnostic concepts in all areas of medicine. Recent advances in material science and strong collaborations crossing disciplines have fostered an integrative concept, ‘theragnostics’, which combines therapeutics with diagnostics for optimum treatment of various diseases.

While several classes of materials, such as fluorescent dyes, magnetic nanoparticles and mesoporous nanoparticles, have been developed as potential theragnostic tools, nanodiamonds are emerging as an excellent candidate for fluorescent biomarkers, nano-scale sensors and versatile drug delivery vehicles. Studies have shown that optical defects in nanodiamonds can be used for cellular labeling *in vitro* and *in vivo* over long time-scales due to their photostability and biocompatibility. Furthermore, these unique defect systems can also be used as sensitive nanoscale sensors of motion and electromagnetic fields.

In this interdisciplinary project, the team aims to combine the reporting capability of these novel optical defects with the nanoscale sensing possibilities to probe the intracellular environment of living biological systems in fundamentally new ways.

Right: Bright field and fluorescent image of nanodiamonds (red)which have been taken up by living cancer cells (blue). (D. Simpson)
Below: Motion of a single nanodiamond in a living cell. (D. Simpson)

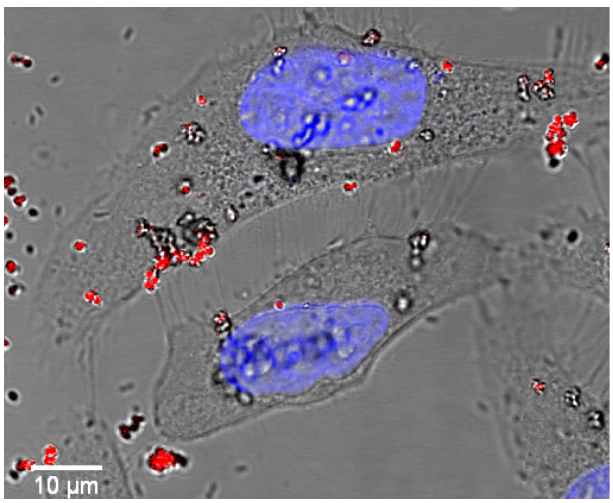


Progress

This interdisciplinary team was able to successfully track the motion of individual nanodiamonds in living cancer cells over unprecedented time scales, providing the first glimpse of how these nanoscale probes can be used as effective biomarkers and reporters of cell activity.

By implementing techniques analogous to traditional magnetic resonance imaging (MRI) the research team has demonstrated that the necessary quantum control techniques can be implemented in the confines of the living cell, thereby paving the way for MRI imaging at the nanoscale.

Over the course of 2010-11, the team was also able to demonstrate that via simple application of a relatively small magnetic field, these bright fluorescent nanodiamonds can be converted into sensitive orientation markers, effectively like a compass inside the cell. Using this technique, the team was able to report the orientation changes of a single nanodiamond over a time scale of hours, with the nanodiamonds acting as both ‘a sensor and a compass’ It is hoped that further application of these novel techniques will allow the targeting of specific biological processes, providing more insight into how cells function at the nanoscale.



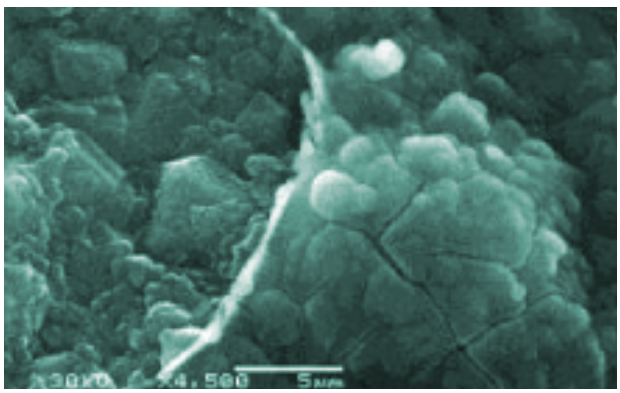
Wireless strain gauges for implant dentistry: towards the bionic bone sensor

Investigators: A/Prof Joseph Palamara, Melbourne Dental School; Dr Janice Kan, Melbourne Dental School; A/Prof Roy Judge, Melbourne Dental School; A/Prof Andrew Greentree, School of Physics; Dr Kate Fox, School of Physics.

Purpose

Implant dentistry is an important field that is essential to the quality of life of people. It is a mature branch of dentistry and the US market is estimated to be worth around $1billion per year. Although most implants have very good outcomes for the patients, there is a small but significant failure rate for implants, and such failures lead to decreased quality of life for the patient and greatly increased cost of care. Optimising implants and predicting failure is therefore an important goal. Such optimisation is difficult at present, as the propagation of force through the bone of a living creature is difficult to measure. Although, there are some excellent results on de-fleshed animal skulls *in vitro,* surgery is required for implantation of strain gauges *in vivo* and the complications of wire connectors mean that wireless solutions are essential for long-term operation for human applications.

The team's solution is to develop a fully biocompatible, robust, wireless strain gauge to allow the monitoring of strain *in vivo*. Commercially bought polycrystalline diamond (PCD) and ultrananocrystalline diamond (UNCD) can be used as a base similar to a silicon microchip for the formation of integrated circuits and sensors.



Above: False colour image of the growth of synthetic bone on a polycrystalline diamond substrate after two weeks suspended in simulated body fluid. (K. Fox) Right: photographic representation of silicon, PCD and UNCD samples exposed to simulated body fluid for 0, 1, 7 and 14 days. (K. Fox)

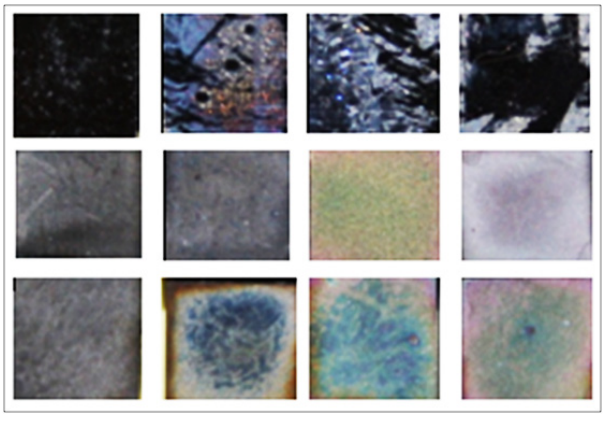
Progress

Diamond possesses many favourable qualities for implantation into living tissue including biocompatibility, biostability and for some applications, hardness. However, the biocompatibility of diamond with bone is not yet proven.

To check this, polycrystalline diamond (PCD) and ultra-nanocrystalline diamond (UNCD) samples were grown in house and placed in a solution of simulated body fluid (SBF), a solution known to "grow" synthetic apatite, a calcium phosphate material comprising the same chemical compound as bone, and the results compared with a silicon substrate as control.

Preliminary results show that hydroxyl-apatite coated UNCD is the preferred substrate for osseointegration. Results have shown that both PCD and UNCD are bioactive and capable of growing bone from an *in vitro* solution of SBF (see image below). X-ray photoelectron spectroscopy analysis shows Ca/P ratios similar to that of other researchers.

The next step is for biocompatibility assessment of diamond samples *in vivo* comparing results of hydroxyapatite (HA)-coated diamond to non-HA-coated diamond. Initial tests will be on animal models, however, the ultimate aim is a device capable of being implanted along with conventional dental implants in humans, to assist clinicians in failure analysis and implant optimisation.



MMI partnerships: "Bring us your problems"

Developing and nurturing strategic partnerships is a high priority for the Institute. We seek to develop deep, long-lasting relationships with organisations who share our passion for addressing 'BHAGs' – Big, Hairy Audacious Goals. By combining the creativity and innovation of researchers at the University with those of our partners, we can have the confidence to embark on projects that have the capacity to bring about transformational change, from alleviating blindness to radically changing the way we view the future of transportation.

better place

The MMI is at the forefront of a new partnership between the University and Better Place Australia. Through an ARC Linkage Project with the School of Engineering the partnership is investigating the effect of mass adoption of electric cars on electricity distribution grids.

CSIRO

The MMI-CSIRO Materials Science PhD Scholarship program not only provides students with broader career options, but also nurtures a new generation of materials researchers and contributes to increased collaboration through joint supervision.

BIONICVISION AUSTRALIA

As a member of the Bionic Vision Australia consortium, the MMI is developing biocompatible, high-density electrode arrays that are key components of the high-acuity bionic eye prosthesis.

Australian Government
Department of Defence
Defence Science and Technology Organisation

With the launch of the Defence Science Institute in 2010, the MMI has formalised the research collaboration with the DSTO. This multidisciplinary engagement includes researchers from the faculties of Science, Engineering, and Medicine, Dentistry and Health Sciences.

Bionic Vision Australia

The MMI is a member of the Bionic Vision Australia (BVA) consortium. BVA is developing a bionic eye to restore some sense of vision to people with degenerative forms of vision impairment, such as retinitis pigmentosa or age-related macular degeneration. MMI's involvement in the project consists in solving the materials-related problems for the design and encapsulation of high-density stimulation electrodes.

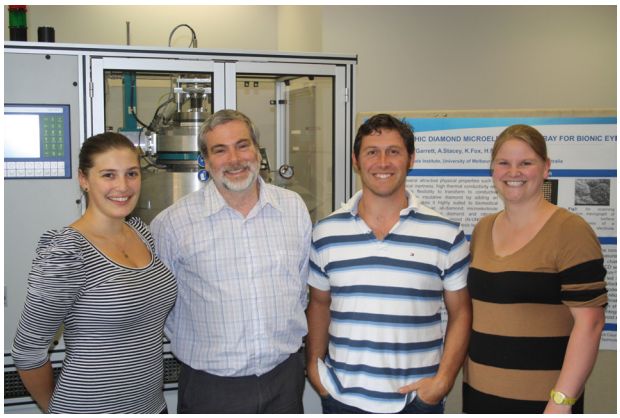
In 2009, the Australian bionic eye project was awarded a $42 million Australian Research Council grant by the Australian Federal Government to develop bionic vision technology. Formally launched in March 2010, BVA brings together researchers from the Bionics Institute, the Centre for Eye Research Australia, NICTA, the University of Melbourne and the University of New South Wales (UNSW). The University of Western Sydney, the National Vision Research Institute (NVRI) and the Royal Victorian Eye and Ear Hospital are project partners. The global goal of the consortium is: "To rapidly develop internationally competitive retinal implants and technologies that are shown to be clinically safe and effective in restoring sight, leading to successful commercialisation."

Two retinal implant prototypes are currently being developed: a wide-view device; and a high-acuity device. The wide-view device incorporates an implanted microchip and 98 electrodes to stimulate the retina. The device aims to enable patients to manoeuvre around large objects such as buildings, cars and park benches. The high-acuity device will also include an implanted microchip and over one thousand stimulation electrodes. This device aims to provide enough visual detail to enable patients to recognise faces and read large print.

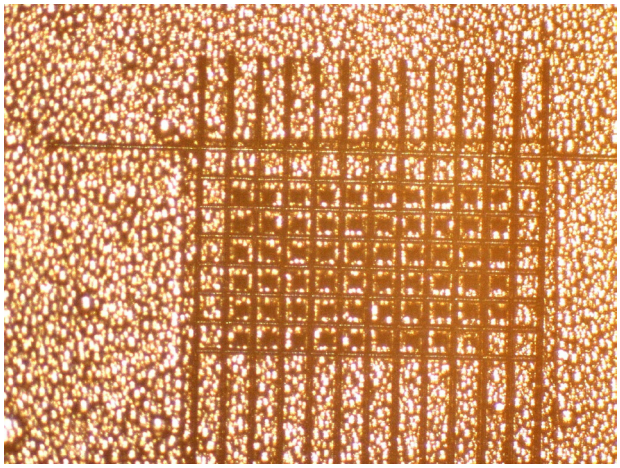
The MMI team, led by Prof Steven Prawer, is working in collaboration with researchers from NICTA on the development of biocompatible, high-density electrode arrays for the high-acuity device. The electrode array is based on ultrananocrystalline diamond and will be encapsulated in a biocompatible and thermally-insulating diamond case.

For more information, visit:

http://www.bionicvision.org.au



The BVA team consists of (left to right) Ms Samantha Lichter (PhD student), Prof Steven Prawer, Dr David Garrett, Dr Kate Fox and Dr Kumar Ganesan (absent from the photo). The team is standing in front of the Microwave Plasma Chemical Vapour Deposition machine, used to grow polycrystalline diamond.



Isolated diamond electrodes for the high-acuity bionic eye device. (K. Ganesan)

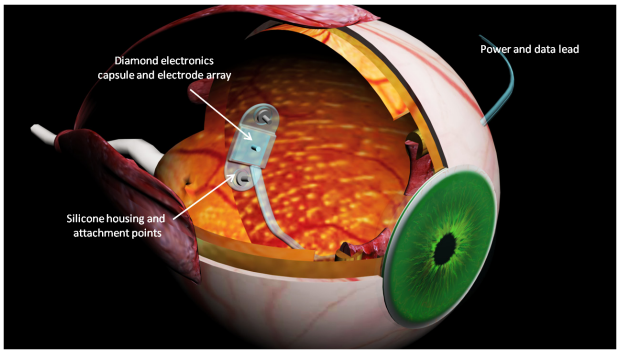
Progress update

In 2011, BVA has made remarkable progress on both its wide-view and high-acuity programs, integrating efforts across activities in device development, stimulation strategy, preclinical, clinical and surgical research. Work is well on track towards the first set of patient tests with the wide-view device in 2013. Similarly, researchers continue to refine the design of the high-acuity device and work through the pipeline of preclinical testing.

The team at the MMI fabricated BVA's first electrode array for the high-acuity device with physically and electrically isolated electrodes. This enables engineers to have control over each electrode and to devise flexible stimulation strategies which can increase the quality of vision experienced by patients. The MMI team has also developed a technique to fabricate and place hermetic feedthroughs that connect the electrode array with the microchip. MMI materials scientists have optimised the laser milling of diamond material to make a box that will encapsulate the device to ensure the electronics do not have adverse affects on the body and vice-versa.

A collaborative research project between MMI and NVRI has recently shown, for the first time, that diamond can be used as a safe material for electrical nerve stimulation. Retinal tissue was electrically stimulated with micro scale diamond electrodes and recordings were made from adjacent retinal cells. The retinal cells were able to be stimulated at currents that are considered safe for the delicate retinal tissue.

In other parts of the BVA project, the first generation microchip for the high-acuity device was developed by microelectronics engineers, fabricated at IBM Australia and successfully bench-tested. The team is now working on a version of the microchip incorporating all required components to drive up to 1000 electrodes. Researchers and surgeons have been improving the design of electrodes and encapsulation for the high-acuity device. This involves developing an appropriate surgical technique to secure the electrode array in place for the long term. Optimising the electrode shape using diamond materials and evaluating the effectiveness of penetrating versus flat electrodes is a critical part of the process.



Artist's impression of the current generation of the BVA epiretinal device, tacked in positioned over the macular. During pre-clinical trials power, and data are fed to the device through a platinum wire lead. Eventually the lead will be replaced with wireless power and data transfer. (D. Garrett)

Student internships

Ms Ella Slonim (undertaking a Bachelor of Biomedicine) completed a three month internship from September to December under the supervision of Dr Kate Fox (Physics) . The aim of her project was to assess the influence on protein adsorption to the impedance of a diamond electrode. She determined that the adsorption of protein on diamond electrodes increases electrochemical impedance thereby reducing electrical stimulation capacity.

Mr Ashley Rozario (Temsasek Polytechnic, Singapore) undertook an internship supervised by Dr Kate Fox (MMI) from September 2011 to January 2012. The aim of his project was to determine whether a polymeric material called parylene-C will adhere to diamond or whether an intermediate layer or chemical treatment is required. Ashley showed that the high-acuity bionic eye electrode will need to have a joining layer before it can be parylene-C coated.

The work of both Ella and Ashley was presented at the 36th Annual Condensed Matter and Materials Meeting (Wagga Wagga, 31 January-1 February 2012).

CSIRO

MMI-CSIRO Materials Science PhD Scholarship program

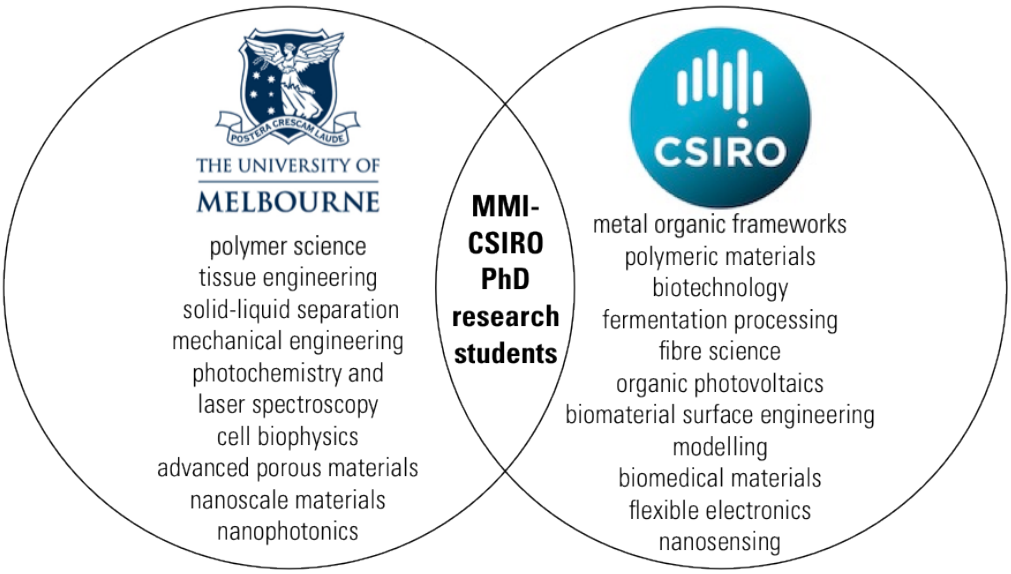
The MMI has forged strong links with the Commonwealth Scientific and Industrial Research Organisation (CSIRO), particularly the CSIRO Materials Science and Engineering (MSE) Division, to collaboratively build research capacity in the area of materials science and engineering, through postgraduate training and supervision.

The MSE Division has over 800 researchers who utilise a diverse range of research capabilities, with an emphasis on working at the interface between biology, chemistry and physics within an engineering framework. MSE researchers seek to improve devices, processes and materials to transform manufacturing and to solve major national and global challenges in areas such as health, energy, water and transport.

Through the Materials Science PhD Scholarship program, the MMI and CSIRO are training the next generation of materials researchers, ensuring continued research excellence in materials science. The program not only provides young researchers with the exposure and cross-organisational experience that will distinguish them from their peers, it also generates new collaborations between the two organisations and strengthens their relationship.

In addition to the co-supervision of scholarship recipients with their UoM counterparts, CSIRO researchers participate in MMI research events - such as the annual materials research workshop and the 'Nano in Medicine' event. By promoting the exchange and transfer of knowledge and skills, the program demonstrates the mutually beneficial outcomes of partnerships, one of the core principles driving MMI's activities.

For more information, visit:
http://www.csiro.au
http://www.materials.unimelb.edu.au



Update

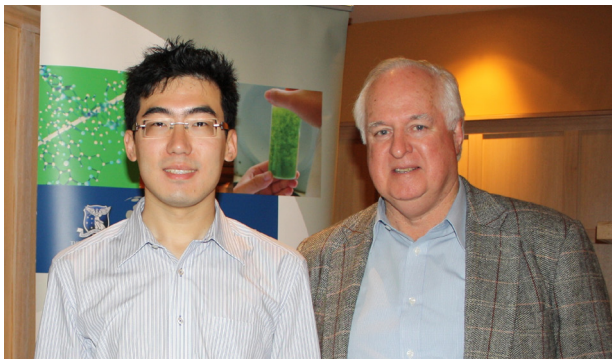
The MMI-CSIRO PhD Materials Science Scholarship program is a competitive scheme providing a scholarship top-up to successful applicants. The funds are provided by CSIRO and administered by the MMI. Successful students undertake a PhD at the University of Melbourne under joint supervision from CSIRO.

The first round of the MMI-CSIRO PhD Scholarship program (November 2010-January 2011) attracted close to 50 applications from excellent domestic and international students. Six students were offered PhD places at the University of Melbourne under the program and five accepted. The program provided each recipient with a top-up to their primary scholarship (typically an Australian Postgraduate Award (APA) or International Postgraduate Research Scholarship (IPRS)) to $30,000 annually, for the 3.5 year life of the PhD.

The second round of the program (May-August 2011) was even more successful, with over 250 applications from students from all around the world. Applications were of very high calibre, with 100 students boasting a preliminary score of 85 or above. Ten students have been offered a top-up scholarship and been allocated supervisors at both organisations. The research areas covered by the students' projects are listed in the diagram on the left page.

In addition, the MMI has received from the DVC(R) four Strategic Research Australian Postgraduate Awards (STRAPAs) in each round, to allocate to materials science postgraduate students. These STRAPAs are available for domestic students only.

The joint endeavour with CSIRO has resulted in an increase in the number of student researchers at CSIRO and greater collaboration between CSIRO and the University.



PhD scholarship recipient Aaron Song with his UoM supervisor Prof Ken Ghiggino (Chemistry).

"The joint supervision from UoM and CSIRO provides me with support in a diverse range of fields, and allows me having access to state of the art facilities for both chemical synthesis and device fabrication." Aaron Song, MMI-CSIRO PhD scholarship recipient.

PhD scholarship recipients Steve Shirbin, Terence Hartnett and Timothy Henderson.

Governance, management and reporting

The MMI is one of five interdisciplinary Research Institutes established by the University of Melbourne in late 2009.

The 'custodial' faculty of the MMI is the Melbourne School of Engineering, therefore the MMI reports on operational matters to the Dean of Engineering. The MMI reports on strategic and financial matters to the Deputy Vice-Chancellor (Research) (DVC(R)).

Reporting

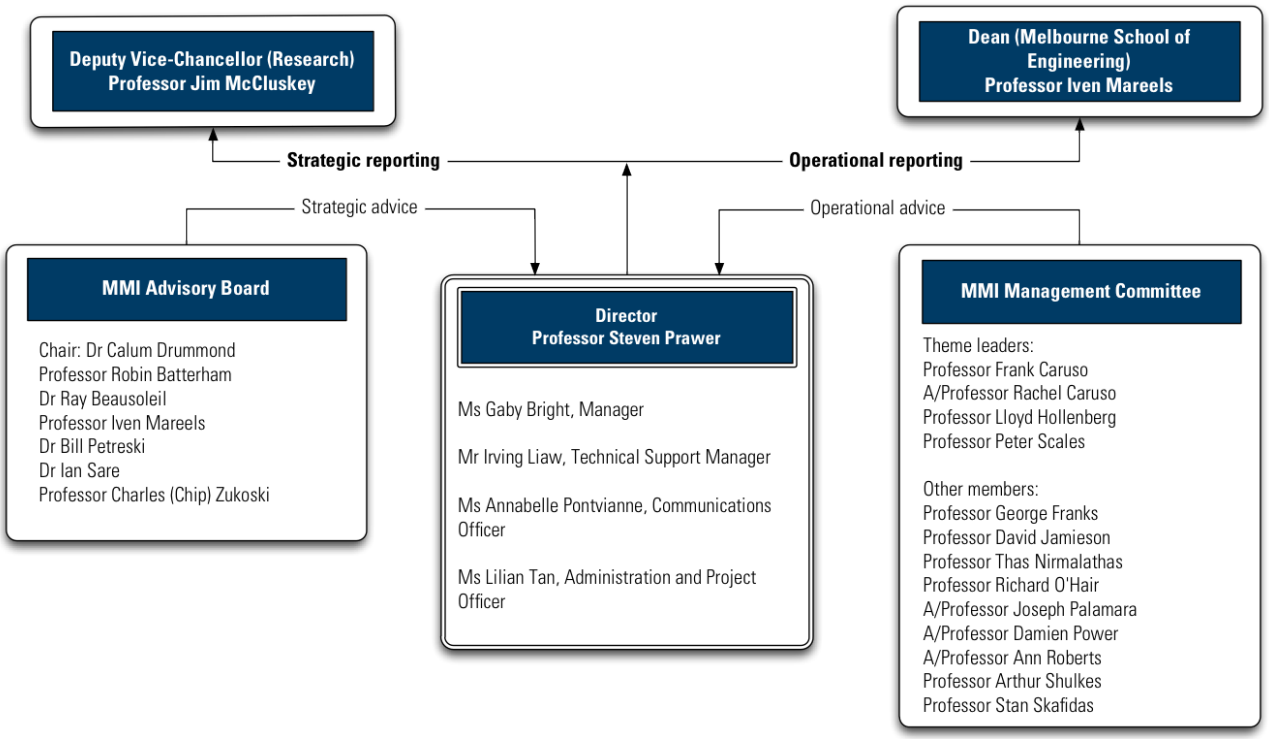
The Institute reports annually on the previous year's activities through the annual report. Monthly reports are provided to the University's Senior Executive through the DVC(R). Financial reports are provided annually.

Planning

Annual plans are provided to the DVC(R), along with strategic plans every three years.

Director and operational staff

The Director is responsible for the leadership of the Institute and the effective operation, including management of the operational team.The make-up of the operational team was bedded down in 2011. The team is led by the Manager who, in addition to the day-to-day management of the Institute, is responsible for the strategic program development. The Technical Support Manager provides support for materials infrastructure activities at the University, including technical seminars. The Communications Officer manages the website, public events and publications and the Project and Administrative Officer is in charge of activities such as the seed funding and scholarship programs and the running of the office and of some events.



Advisory Board

The Advisory Board provides high-level strategic advice to the Director and Management and promotes the interests of the Institute within the broader community. The Board is primarily composed of members external to the University representing research, industry, and government. The Advisory Board was formed in 2011; the first meeting will be held in early 2012.

Advisory Board members

- Chair: Dr Calum Drummond , Group Executive, Manufacturing, Materials and Minerals, CSIRO.
- Prof Robin Batterham, Kernot Professor of Engineering, University of Melbourne
- Dr Ray Beausoleil, HP Fellow, Intelligent Infrastructure Lab, Hewlett Packard
- Prof Iven Mareels, Dean of Engineering, University of Melbourne
- Dr Bill Petreski, Principal Adviser, Technology Industry, Australian Industry Group
- Dr Ian Sare, (in 2011) acting Chief Defence Scientist, Defence Science and Technology Organisation, Department of Defence
- Prof Charles (Chip) Zukoski, Chairman, Science and Engineering Research Council (SERC), A*STAR, Singapore; William and Janet Lycan Professor, Department of Chemical and Biomolecular Engineering, University of Illinois at Urbana-Champaign.

Management Committee

The Management Committee provides advice to the Director on matters such as research development and the quality of MMI research activities. The Committee is comprised of MMI Research Theme Leaders, Associate Deans (Research) of collaborating Faculties, and other University staff with experience or accountability relevant to materials research. Members undertake significant involvement in MMI-represented research and advancement activities and make a substantial contribution to Institute outcomes.

The Management Committee held nine meetings in 2011: 2 March, 13 April, 18 May, 22 June, 20 July, 17 August, 21 September, 19 October and 16 November.

Management Committee members

- Prof Frank Caruso, Theme Leader (Nanomedicine), Dept of Chemical and Biomolecular Engineering
- A/Prof Rachel Caruso, Theme Leader (Materials for energy), Dept of Chemistry
- Prof George Franks, Dept of Chemical and Biomolecular Engineering
- Prof Lloyd Hollenberg, Theme Leader (Quantum technologies), Dept of Chemical and Biomolecular Engineering
- Prof David Jamieson, School of Physics
- Prof Thas Nirmalathas, Dept of Electrical and Electronic Engineering
- Prof Richard O'Hair, Associate Dean (Research), School of Chemistry
- A/Prof Joseph Palamara, School of Dental Science
- A/Prof Damien Power, Dept of Management and Marketing
- A/Prof Ann Roberts, School of Physics
- Prof Peter Scales, Associate Dean (Research), Theme Leader (Materials processing), Dept of Chemical and Biomolecular Engineering.
- Prof Arthur Shulkes, Associate Dean (Research), Faculty of Medicine, Dentistry and Health Sciences
- Prof Stan Skafidas, Dept of Electrical and Electronic Engineering.

Selected publications from 2011

The following papers represent some of the highlight publications for our various research themes and seed funding recipients. Ordered alphabetically by first author, they cover the themes of Materials for energy, Materials processing, Nanomedicine and Quantum technologies. The listing covers only journal articles that were published in 2011, not those selected for publication in 2011 but not published until 2012. It doesn't include conference proceedings.

Journal articles

Anderson, C.J., Tao, W., Scholes, C.A., Stevens, G.W. & Kentish, S.E. (2011). The performance of carbon membranes in the presence of condensable and non-condensable impurities. *Journal of Membrane Science, 378*, 117-127.

Baldwin, A.J., Knowles, T.P.J., Tartaglia, G.G., Fitzpatrick, A.W., Devlin, G.L., Shammas, S.L., … Dobson, C. M. (2011). Metastability of native proteins and the phenomenon of amyloid formation. *Journal of the American Chemical Society, 133*(36), 14160-14163.

Barrow, S. J., Funston, A. M., Gomez, D. E., Davis, T. J. & Mulvaney, P. (2011). Surface plasmon resonances in strongly coupled gold nanosphere chains from monomer to hexamer. *Nano Letters, 11*(10), 4180-4187.

Berry, J.D., Davidson, M.R., Bharti, R.P. & Harvie, D.J.E. (2011). Effect of wall permittivity on electroviscous flow through a contraction. *Biomicrofluidics Journal, 5*, 044102.

Chandrawati, R., van Koeverden, M. P. Lomas, H. & Caruso, F. (2011). Multicompartment particle assemblies for bioinspired encapsulated reactions. *Journal Physical Chemistry Letters, 2*(20), 2639-2649. DOI: 10.1021/jz200994n

Chen Y., Huang F. Z., Chen D. H., Cao L., Zhang X. L., Caruso R. A. & Cheng Y.-B. (2011). Effect of mesoporous TiO_2 bead diameter in working electrode on dye-sensitised solar cell efficiency. *ChemSusChem, 4*, 1498-1503.

Chen, G.Q., Scholes, C.A., Qiao, G.G. & Kentish, S.E. (2011). Water vapor permeation in polyimide membranes. *Journal of Membrane Science, 379*(1-2), 479-487.

Chuanuwatanakul C., Tallon C., Dunstan D. E. & Franks G. V. (2011). Controlling the microstructure of ceramic particle stabilised foams: influence of contact angle and particle aggregation. *Soft Matter, 7*, 11646-11474.

Go, D.P., Gras, S.L., Mitra, D., Nguyen, T.H., Stevens, G.W., Cooper-White, J.J. & O'Connor, A.J. (2011). Multilayered microspheres for the controlled release of growth factors in tissue engineering. *Biomacromolecules, 12*(5), 1494-1503.

Goh, X.M., Lin, L. & Roberts, A., (2011). Plasmonic lenses for wavefront control applications using two-dimensional nanometric cross-shaped aperture arrays. *Journal of the Optical Society of America B, 28*(3), 547-553.

Hajimohammadi, A., Provis, J.L. & van Deventer, J.S.J. (2011). Time-resolved and spatially-resolved infrared spectroscopic observation of seeded nucleation controlling geopolymer gel formation. *Journal of Colloid and Interface Science, 357*(2), 384-392.

Huang F. Z., Chen D. H., Cao L., Caruso R. A. & Cheng Y.-B. (2011). Flexible dye-sensitised solar cells containing multiple dyes in discrete layers. *Energy & Environmental Science, 4*, 2803-2806.

Ide A., Drisko G. L., Scales N., Luca V., Schiesser C. H. & Caruso R. A. (2011). Monitoring bisphosphonate surface functionalization and acid stability of hierarchically porous titaniuam zirconium oxides. *Langmuir, 27*, 12985-12995.

Johnston, A. P. R., Such, G. K., Ng, S. L. & Caruso, F. (2011) Challenges facing colloidal delivery systems: from synthesis to the clinic. *Current Opinion in Colloid & Interface Science, 16*(3), 171-181.

Leung, M. K. M., Such, G. K., Johnston, A. P. R., Biswas, D. P., Zhu, Z., Yan, Y., Lutz, J.-F. & Caruso, F. (2011). Assembly and degradation of low-fouling click-functionalised poly(ethylene glycol)-based multilayer films and capsules. *Small, 7*(8), 1075-1085.

Liang, K., Such, G. K., Zhu, Z., Yan, Y., Lomas, H. & Caruso F. (2011). Charge-shifting click capsules with dual-responsive cargo release mechanisms. *Advanced Materials, 23*(36), H273-H277.

Lin, L. & Roberts, A., (2011). Light transmission through nanostructured metallic films: coupling between surface waves and localised resonances. *Optics Express, 19*(3): 2626-2733.

McGuinness, L. P., Yan, Y., Stacey, A., Simpson, D. A., Hall, L. T., Maclaurin, D., … Hollenberg, L. C. L. (2011). Quantum measurement and orientation tracking of fluorescent nanodiamonds inside living cells. *Nature Nanotechnology, 6*, 358-363.

Roberts, A. & Lin, L., (2011). Substrate and aspect-ratio effects in resonant nanoaperture arrays. *Optical Materials Express, 1*(3), 480-488.

Such, G. K., Johnston, A. P. R. & Caruso, F. (2011). Engineered hydrogen-bonded polymer multilayers: from assembly to biomedical applications. *Chemical Society Reviews, 40*, 19-29.

Sulistio A., Lowenthal J., Blencowe A., Bongiovanni M. N., Ong L., Gras S. L., Zhang X., & Qiao G. G. (2011). Folic acid conjugated amino acid-based star polymers for active targeting of cancer cells. *Biomacromolecules, 12*(10), 3469.

Tabor, R.F., Manica, R., Chan, D.Y.C., Grieser, F. & Dagastine, R.R. (2011). Repulsive van der Waals forces in soft matter: Why bubbles do not stick to walls. *Physical Review Letters, 106*(6), 4501-4501.

van Deventer, B.B., Usher, S.P., Kumar, A., Rudman, M., & Scales, P.J., (2011). Aggregate densification and batch settling. *Chemical Engineering Journal, 171*(1) 141-151.

Vernon K. C., Gomez D. E., Davis T. J. & Tischler N., (2011). Simulations of the effect of waveguide cross-section on quantum dot—plasmon coupling. *Journal of Applied Physics, 110*(7), 074315.

Wang, Y., Hosta-Rigau, L., Lomas, H. & Caruso, F. (2011). Nanostructured polymer assemblies formed at interfaces: applications from immobilization and encapsulation to stimuli-responsive release. *Physical Chemistry Chemical Physics, 13*, 4782-4801.

Xu W., Figueiredo R. B., Wu X., Pauly S., Stoica M., Eckert J., Langdon T. G. & Xia K., (2011). Intrinsically ductile failure in a nanocrystalline beta titanium alloy with high Poisson's ratio. *Advanced Engineering Materials, 13*(12) 1108-1113.

Yan, Y., Such, G. K., Johnston, A. P. R., Lomas, H. & Caruso, F. (2011). Toward therapeutic delivery with layer-by-layer engineered particles. *ACS Nano, 5*(6), 4252-4257.

Yan, Y., Wang, Y., Heath, J. K., Nice, E. C. & Caruso, F. (2011). Cellular association and cargo release of redox-responsive polymer capsules mediated by exofacial thiols. *Advanced Materials, 23*(34), 3916-3921.

Finance

INCOME		
Core University funding		945,000.00
Supplementary University funding		92,000.00
Strategic University funding		15,000.00
Miegunyah Visiting Fellow Program		14,700.00
External funding		238,984.51
	TOTAL	$1,305,684.51

EXPENDITURE	
Operating expenditure	574,551.89
Salaries	465,841.42
Administration and other costs	108,710.47
Research enabling expenditure	675,998.18
Research project seed funding	219,000.00
Strategic research initiatives	90,000.00
PhD top-up scholarships	232,050.00
Research events and promotions	29,808.92
Visiting fellows	21,193.49
Technical support program	67,934.02
Other research support	16,011.75
TOTAL	$1,250,550.07

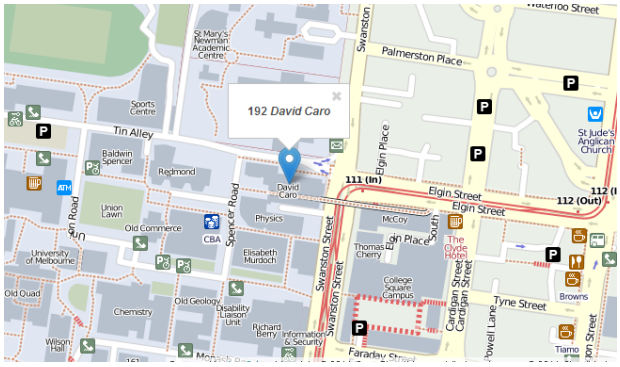
Contact details

Melbourne Materials Institute

General enquiries
Tel: +61 3 8344 6415
Fax: +61 3 9347 4783
Email: materials-info@unimelb.edu.au

Address
Room 159, Ground Floor
David Caro buildng
Corner Tin Alley and Swanston Street
The University of Melbourne
3010, Victoria, Australia

Web
www.materials.unimelb.edu.au



Director
Prof Steven Prawer
Tel: +61 3 8344 5460
Email: s.prawer@unimelb.edu.au

Manager
Ms Gabrielle Bright
Tel: +61 3 8344 6415
Email: gbright@unimelb.edu.au

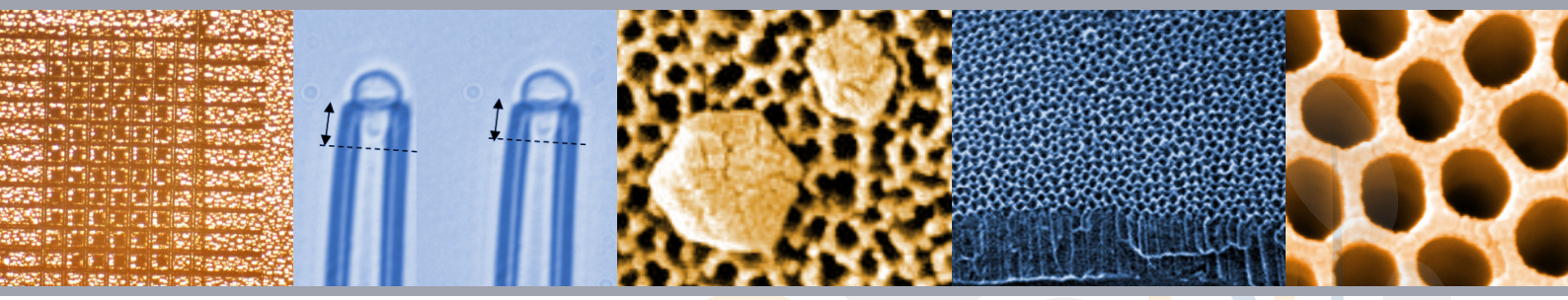
Technical Support Manager
Mr Irving Liaw
Tel: +61 3 8344 0176
Email: iliaw@unimelb.edu.au

Communications Officer
Ms Annabelle Pontvianne
Tel: +61 3 9035 3828
Email: pa@unimelb.edu.au

Project and Administrative Officer
Ms Lilian Tan
Tel: +61 3 8344 6415
Email: lj.tan@unimelb.edu.au

Melbourne Materials Institute

For more information visit our website at www.materials.unimelb.edu.au



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General enquiries:
Email: materials-info@unimelb.edu.au
Telephone: +61 3 8344 6415
Facsimile: + 61 3 9347 4783