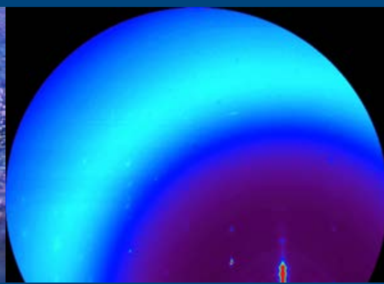
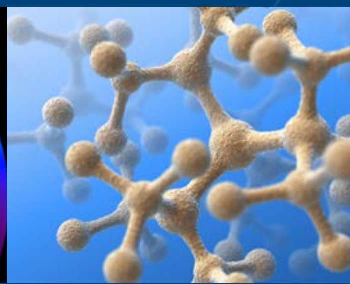
THE UNIVERSITY OF MELBOURNE

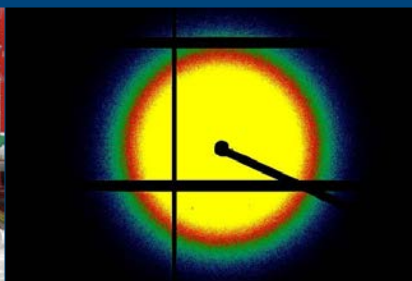
MELBOURNE MATERIALS INSTITUTE

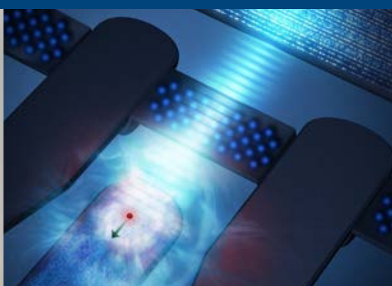
Melbourne Materials Institute

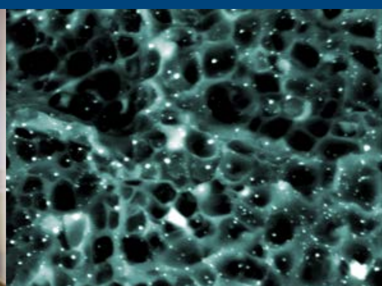
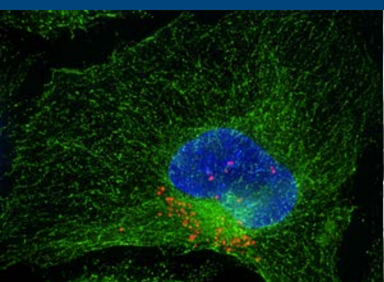
Annual Report 2012




Front cover images, from left to right:

First row:

1. Dr Paolo Falcaro (right) and PhD scholarship recipient Fabio Lisi examine vials of quantum dots in the lab. Credit: CSIRO.
2. Diamond box that will house the Bionic Vision Australia (BVA) high-acuity device. The device is shown on the pads of an SD flash memory card to give a sense of scale. Credit: D. Garrett (BVA).
3. Left: X-Ray diffraction pattern obtained at the Australian Synchrotron on one of Dr David Jones' team's new materials. Analysis of the pattern will allow determination of the processes involed in controlling the nano-scale organisation of the materials in printed solar cells.
4. Molecular structure (iStock).

Second row:

1. Airliner flying around globe (iStock).
2. Dr Ian MacLeod (Western Australian Museum) and Marcelle Scott (Centre for Cultural Materials Conservation) deconcreting iron corrosion products prior to further analysis and conservation at Heritage Victoria conservation labs. Credit: J. Walton.
3. A colour-contrast image of the first small angle X-ray scattering of glycogen. Particle density and shape imformation can be deduced from this image. Credit: Q. Besford, A. Gray-Weale.
4. Audience of MMI public lecture. Credit: Casamento Photography.

Third row:

1. Prof David Awschalom (UCSB) talking to fellow researchers and students from the University. Credit: Casamento Photography.
2. Artist's impression of a phosphorus atom in the middle of an electron 'cloud'. Credit: T. Melov.
3. MMI event. Credit: Casamento Photography.
4. False colour high-resolution image of nanocomposite showing metal nanopoarticles dispersed inside a polymer matrix. Credit: P. Tran, D. Hocking and A. O'Connor.

Fourth row:

1. Deconvolution microscopy image of HeLa cells internalising nanoengineered polymer particles. The nucleus is in blue, microtubules are in green and particles are in red. Credit: Y. Yan.
2. The Melbourne Centre for Nanofabrication (MCN), Clayton,Victoria. Credit: MCN.
3. One of BVA's high-acuity pre-clinical bionic eye prototypes. Credit:O. Burns (Bionics Institute).
4. Dr Arman Ahnood and Dr Kumar Ganesan (BVA). Credit: J. Vittorio.

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Melbourne Materials Institute

Annual Report

2012

This report presents a summary of MMI activities and materials research broadly at the University of Melbourne. Funding for this work has come from sources including the University of Melbourne, the Australian Research Council, the National Health and Medical Research Council, the Victorian Government, the Australian Federal Government and industry partners.

Contents

Chair's welcome

It has been my pleasure to chair the MMI Advisory Board in 2012. The first meeting of the Board, in February 2012, was timely, with much of the year's meetings focused on the development of the MMI's Strategic Plan (2013-2015).

Board members have had the opportunity to provide input to the strategy and to advise the Institute on options to increase external partnerships and to create new research opportunities for MMI researchers. The advisory board endorsed the Strategic Plan and I anticipate that we will soon see the benefits of the new external focus.

With the establishment of the Platform Development Pilot Program and increased engagement with the Melbourne Centre for Nanofabrication, the MMI is increasing access to the highly specialised support needed to undertake materials research. In 2012 the MMI has continued the excellent program of public events, promoting materials research, and the CSIRO-MMI Materials Science PhD scholarships.

The advisory board members bring a broad range of experience and expertise, and the MMI has, in turn, leveraged these links. Through the Australian Industry Group the MMI is creating new partnerships and this can be expected to increase in the future.

On behalf of the MMI Advisory Board I congratulate the MMI Director and his team on the positive outcome of the external review of the Institute that was completed in November 2012. I would also like to thank the members of the external review panel for their thoughtful and considered feedback and advice.

I commend to you this annual report, a summary of the excellent research supported and initiated by the Melbourne Materials Institute in 2012.

Calum Drummond
Chair, MMI Advisory Board
Group Executive, CSIRO Manufacturing, Materials and Minerals

Director’s report

As is evident from the pages in this report, the University of Melbourne is home to a rich and vibrant materials science and engineering research community, producing outstanding results which are published in the world’s best journals. As director, it is a rare privilege to witness and support the work of colleagues from across the University on interdisciplinary projects ranging from art conservation to high performance materials for hypersonics and aluminium smelting.

I would like to express my gratitude to the members of the advisory board, so ably chaired by Dr Calum Drummond, for their sage suggestions as to how the Institute can best leverage its opportunities and develop an outward-focused and effective engagement strategy. The fruits of these labours will hopefully become evident in 2013 as the relationships we have developed with the Australian Industry Group and the CSIRO mature into large scale collaborative projects. The smooth running of the Institute and its programs is dependent on the work of a small team of highly committed individuals. My heartfelt thanks are due to our Institute Manager Gaby Bright, Communications Officer Ms Annabelle Pontvianne, Technical Manager Irving Liaw and Project and Administrative Officer Lillian Tan. Together they form a team that are the envy of many in the University.

Finally, I would like to return to a theme that I first raised at the launch of the Materials Institute in 2010: advanced materials are the unsung heroes of our technological age. Despite the fact that they underpin every aspect of our lives, from medical implants to computers, their role in the economy is generally underappreciated, as is the potential of new materials to increase the competitiveness of existing industries and to spawn new enterprises. We cannot wait for Australian industry to come to us seeking advice, inspiration and innovation. Rather, we need to actively seek out businesses which can benefit from our emerging technologies and from the creativity and enthusiasm of our students. If we do this well, we will become an integral part of the innovation economy and will enjoy seeing our creations have a lasting impact. This is a key mission for the Melbourne Materials Institute.

S. Prawer

Professor Steven Prawer, MMI Director

Governance, management and reporting

The MMI is one of six interdisciplinary Research Institutes established by the University of Melbourne. The host faculty of the MMI is the Melbourne School of Engineering and 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

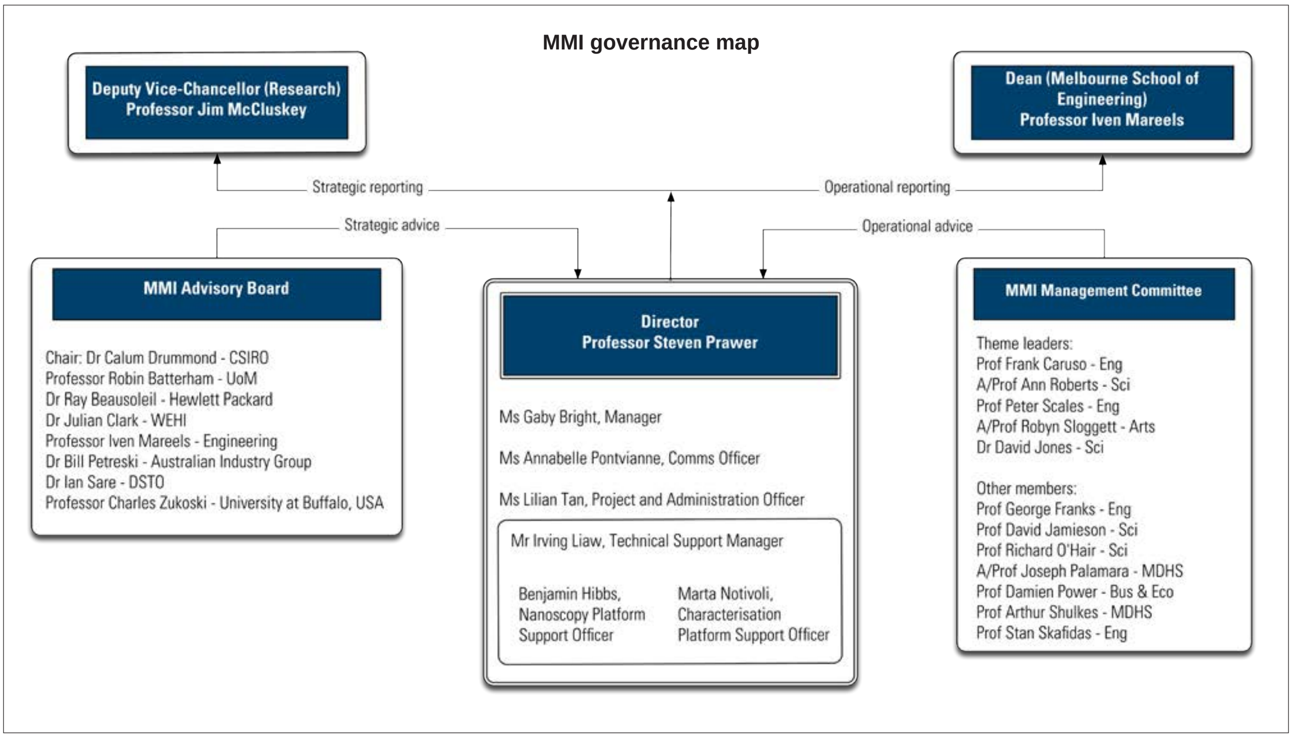
The Institute reports annually on the previous year's activities through the annual report. Monthly reports are provided to the University's Senior Executive and Academic Board through the DVC(R). Financial reports are provided to the DVC(R) every six months.

Planning

Annual activity plans are provided to the DVC(R). Strategic plans are provided every three years.

Director and operational staff

The director is responsible for the leadership and the effective operation of the Institute. The operational 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 communications officer manages the website, public events and publications and the project and administrative officer manages the Interdisciplinary Seed Funding and scholarship programs. The MMI technical program includes the Platform Development Pilot Program, the MCN Access Scheme and technical seminars. It is led by the technical support manager, assisted by two platform support officers. A third platform support officer will be appointed in 2013.



Advisory board

The advisory board provides high-level strategic advice to the director and management team 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 and met for the first time on 1 March 2012. Members met again on 8 August 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;
- Dr Julian Clark, Head of Business Development, Walter and Eliza Hall Institute;
- Prof Iven Mareels, Dean of Engineering, University of Melbourne;
- Dr Bill Petreski, Principal Adviser, Technology Industry, Australian Industry Group;
- Dr Ian Sare, Deputy Chief Defence Scientist (Platforms and Human Systems), Defence Science and Technology Organisation;
- Prof Charles (Chip) Zukoski, Provost & Executive Vice President (Academic Affairs), University at Buffalo, The State University of New York.

Management committee

The management committee meets every two months to provide advice to the director on matters such as research development and the quality of MMI activities. The committee comprises 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 six meetings in 2012: 1 February, 14 March, 9 May, 11 July, 12 September, 14 November.

Management committee members

- Prof Frank Caruso, theme leader (Materials for medicine), Dept of Chemical and Biomolecular Engineering;
- Prof George Franks, Dept of Chemical and Biomolecular Engineering;
- Prof David Jamieson, School of Physics;
- Dr David Jones, theme leader (Materials for energy), School of Chemistry;
- 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, theme leader (Quantum and nanophotonic materials), School of Physics;
- Prof Peter Scales, Deputy Dean, 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;
- A/Prof Robyn Sloggett, theme leader (Materials conservation), School of Historical and Philosophical Studies.

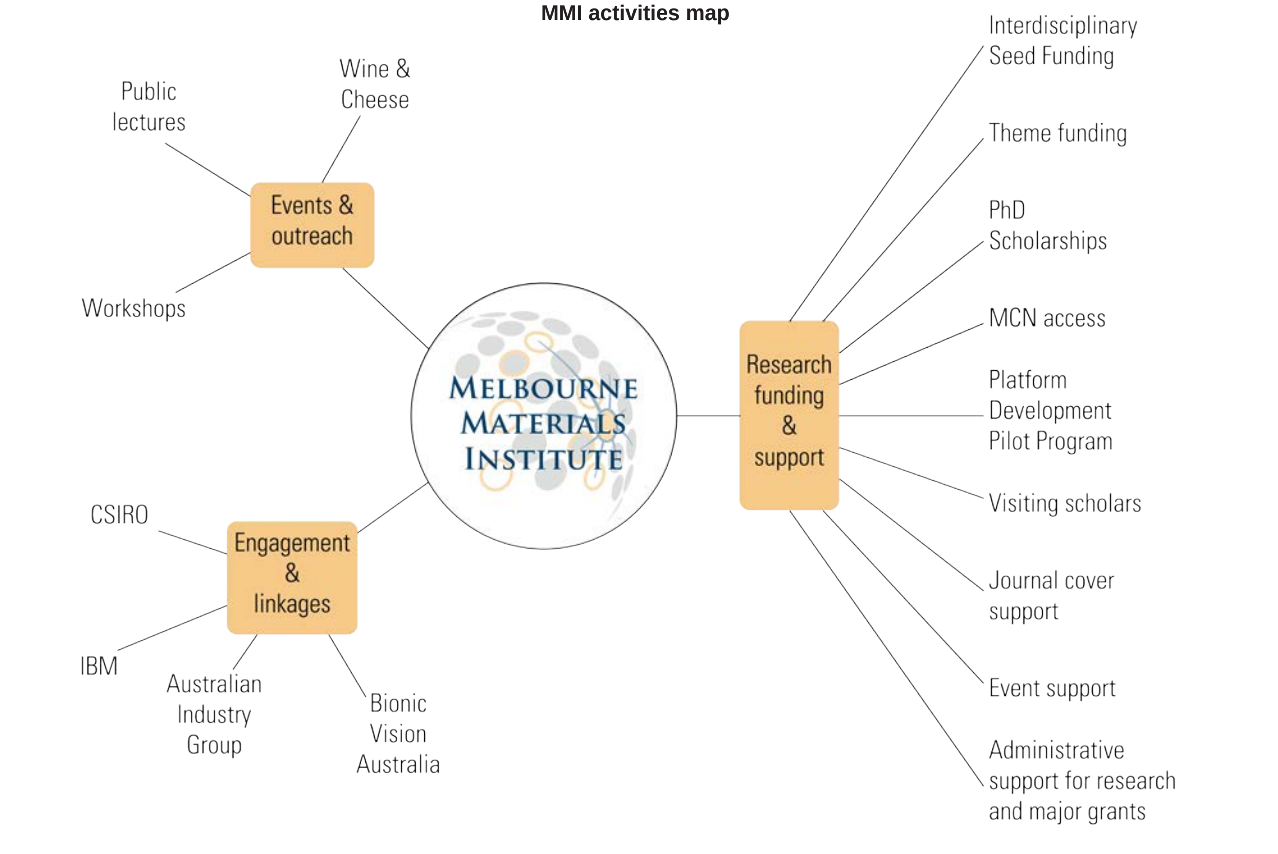
Activities map

The MMI's activities fall under three categories: research funding and support, engagement and linkages, and events and outreach. Each of these areas aims to enhance the materials research capacity of the University:

- Research funding and support: while most of our funding opportunities consists of direct financial support, we also offer assistance with research-related activities such as visits from international collaborators, publications and events.
- Engagements and linkages: by nurturing and developing relationships with external partners, we provide opportunities for new collaborations and offer postgraduate students a broader research experience and the chance to work on current research problems.
- Events and outreach: through public and research events, as well as presentations tailored to specific audiences, we showcase the University's achievements in materials science and provide a space for researchers and external parties to interact, exchange and develop new ideas.

More details on all the activities below can be found in this document.

MMI activities map



Strategic plan

The MMI Strategic plan was developed during 2012 in consultation with our members through targeted focus groups (postgraduates and Early Career Researchers, mid-career researchers and professional staff, and senior academics) and one-on-one discussions with professional and academic staff. In addition, our management committee, advisory board and external stakeholders reviewed the plan and provided input.

In order to strengthen the University research capacity in 2013 we will shift our focus from building and supporting internal interdisciplinary research to brokering new partnerships with individuals and organisations external to the University.

Our core objectives are:

- to build institutional research capacity
- to increase knowledge transfer and build profile and
- to create new links and partnerships.

They manifest in the virtuous cycle for research (see below), to strengthen our materials research capacity.

Purpose

Our purpose is to accelerate materials research opportunities and outcomes by brokering research partnerships with external collaborators, and facilitating interdisciplinary research.

People

The breadth and depth of our capabilities in materials research come from the expertise of our people combined with the technical platforms that underpin the research.

Partnerships

The MMI is a portal to the materials research capabilities at the University of Melbourne. We work to catalyse the University's capabilities, identify partners, and, where necessary, build the capability to support these new partnerships.

Values

In our partnerships and research we value excellence and creativity.

We aim to be proactive in our undertakings and open in our partnerships.

We aim to operate and present ourselves with professionalism and flexibility.

At the end of the day, we want to make a difference and have impact.

Our future

The Melbourne Materials Institute aims to become a trusted advisor to government and industry, and a highly desirable research and development partner.

MMI review

Review panel

The MMI, along with the four other interdisciplinary Melbourne Research Institutes established in 2009, was reviewed in November 2012. The membership of the review panel was:

- Prof Liz Sonenberg, Pro Vice-Chancellor (Research Collaboration), Chair;
- Prof Iven Mareels, Dean (Engineering), host Dean;
- Prof Rob Saint, Dean (Science), non-host Dean;
- Dr Cathy Foley, Chief, CSIRO Materials Science and Engineering Division, external member.

During the review, the panel met with MMI researchers, PhD students and external partners, and were provided with documentation outlining the achievements of the MMI and letters of support.

Criteria

The criteria used to assess the success of the Institute, after the initial three year establishment period, were:

- Success in fulfilling the University's strategic research objectives in tackling the key issues faced by society
- Degree of multi and interdisciplinarity achieved
- Engagement with a broad spread of academic staff and research students from across the University
- Engagement with external organisations and partners
- Added value from research income, publications output and research impact
- Attraction and retention of high quality research higher degree students in interdisciplinary studies
- External recognition of the Institute as a centre of excellence by a range of stakeholders
- Media coverage for both the Institute and staff linked to it.

Outcomes

The review report from panel provided comments for each of the criteria. The panel noted that:

- The MMI has been successful in promoting interdisciplinary research and has promoted innovative projects that might otherwise not have been funded.
- The MMI has successfully developed relationships with CSIRO, the Defence Science and Technology Organisation, and Bionic Vision Australia.
- The Platform Development Pilot Program has been well received and is paving the way for a whole of University policy of support for research infrastructure.
- The MMI is well managed by a small, but effective team.

Recommendations

The review panel identified important opportunities for development of the Institute, including:

- Expanding the reach of activities to include broader representation from the Faculty of Arts, the Faculty of Business and Economics, and the Victorian College of the Arts.
- Playing a central role in the development of a University PhD program in Materials Science.
- Empowering theme leaders to enable them to play a greater role in the development of strategic directions for the Institute.
- Developing an expanded program for brokering non-traditional sources of research funding.

Common issues

Some issues raised were common to all of the Melbourne Research Institutes. They included:

- The quantification of the return on the investment the University has made in the Institutes
- The roles and rewards for theme leaders and deputy directors
- The role of the institutes in the University's international research agenda
- The overlap between the Institutes and the Carlton Connect initiative.

MMI survey

Process

The MMI undertook a survey in May 2012 to obtain feedback from members, partners and stakeholders more broadly. All faculties, except the Melbourne Law School and the Faculty of Veterinary Science, were represented by the 79 respondents. Researchers from all career stages, as well as professional staff, contributed to the findings. Key data is presented here.

Results

The free text comments provided some particularly useful insights; highlights include:

- "The MMI is an excellent platform for researchers to collaborate in materials research, and represents the University's international reputation in materials science."
- "Minimal reporting allows researchers to focus on the research and its outcomes. "
- "This seed funding has allowed for the fostering of new projects that would otherwise be difficult to develop."
- "The diversity of programs and research partnerships is fascinating and events are always inspirational."

Responses

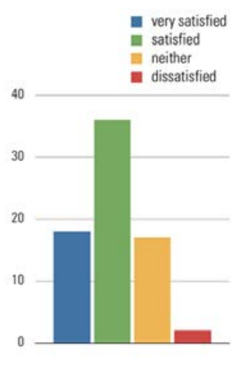
The constructive feedback we have received has enabled us to refine the focus of our programs and better communicate our activities.

Concerns were expressed that the Institutes should not be setting up individual platforms. The platform support program that began in 2012 is a pilot only, to demonstrate the value of central management. If successful, the model could be adopted centrally.

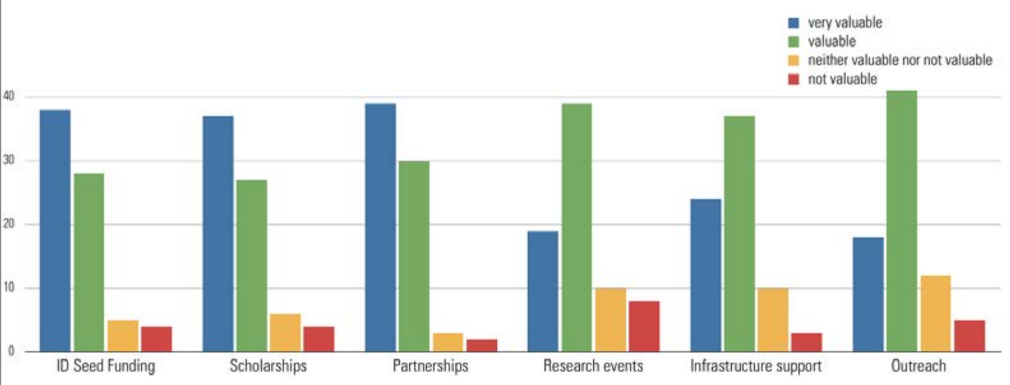
In response to concerns about the transparency of our selection process for the Interdisciplinary Seed Funding scheme, we have provided more details on our website (see also page 37).

As part of our 2013-2015 strategic plan and requests for more support for external engagement, we will employ a dedicated industry partnerships manager in 2013.

Overall satisfaction with MMI's support



Value of MMI activities as rated by survey respondents



2012 in review

This section presents an overview of MMI's activities and achievements in 2012 and a review of some of the University's materials research successes and media mentions.

Funding research

Theme

In 2012, MMI theme leaders were allocated $20 000 from the MMI budget to support research in their theme. Theme leaders directed where this funding was spent and expenditure across the themes was varied. Activities supported included overseas conference travel for post-docs, interstate visitors and international workshops. Further details are provided in the finance section at the end of this report.

Particulate Fluids Processing Centre

The MMI committed to provide $50 000 to the Particulate Fluids Processing Centre (PFPC) in 2011 and 2012. The PFPC is a Special Research Centre of the Australian Research Council based at the University of Melbourne. The Centre brings together internationally renowned researchers to form one of the world's leading multidisciplinary research centres in interfacial science and engineering.

Funding from the MMI supported the PFPC's postgraduate students to run a fortnightly seminar series which provides an important aspect to their training in communication and networking skills. As an added incentive, members who are regular participants in the seminar series (as both presenters and attendees) are eligible for PFPC travel grants to attend both a local and an international conference during their time in the PFPC. A key focus in 2012 was the PFPC's international linkages. Support from the MMI has helped to facilitate incoming and outgoing visits to strengthen existing relationships and to consolidate emerging partnerships.

Travel grants from the PFPC helped postdoctoral fellows like Dr Katharina Ladewig (second from right) to attend international conferences such as the *9th World Biomaterials Congress*, 1-5 Jun, Chengdu, China. Image courtesy of K. Ladewig.

PhD scholarships

In response to the changing demands of scientific research, the MMI has created two PhD scholarship programs and plans are under way to extend the scheme to other partners including IBM. In light of the increasing need to bring disciplines together and of the value of partnering with industry, the programs offer supervision by two or more experts from different fields or organisations and access to an extensive array of equipment, in addition to financial support.

MMI–CSIRO Materials Science PhD scholarship program

Launched in 2010 the MMI–CSIRO Materials Science PhD Scholarship program offers postgraduate students the opportunity to be jointly supervised by experts from the University of Melbourne and CSIRO and to access infrastructure at both institutions. Providing scholarships top-ups to $30 000 *per annum*, the program is an effective recruitment tool and has been successful in attracting high-calibre national and international students. The program has also significantly strengthened research in this area and brought researchers from both organisations into closer collaboration.

In 2012, the MMI recruited seven PhD students from three countries. They are undertaking a variety of interdisciplinary research including projects that aim to develop sources of renewable energy and to enable early detection of emerging viruses.

Building on its success in the last three years, the scholarship program, which started as partnership with CSIRO's Materials Science and Engineering Division, has now been extended to the Process Science and Engineering Division. For more information about this scholarship program, go to the dedicated section on p55.

Interdisciplinary PhD scholarship program

In 2012, the MMI launched a new PhD scholarship program for interdisciplinary materials research. The Interdisciplinary PhD Scholarship program aims to foster the next generation of materials researchers through supervision by two or more University research leaders from different fields.

The program is open to domestic and international students and scholarships are available through the new International Postgraduate Scholarship Fund and the Institute's allocation of Strategic Australian Postgraduate Awards.

Projects offered as part of the program build on outcomes from research funded through the Interdisciplinary Seed Funding scheme. Thirteen projects were advertised and over fifty applications received, of which more than twenty meet the selection criteria. Two applicants were awarded a scholarship and applications for some projects are still open. Descriptions of projects are available on the MMI website.

Interdisciplinary Seed Funding

As part of the University's Interdisciplinary Seed Funding (IDSF) scheme, ten projects selected in 2011 were funded in 2012 and are presented in the IDSF section of this report (see p37).

2012 in review

Supporting research

Prof David Awschalom (University of California Santa Barbara) talking to fellow researchers and students from the University. Credit: Casamento Photography.

International visitors

The MMI assists researchers or groups wishing to host visitors from local or international universities to build or further materials research collaborations. The Institute provide $3 000 towards the visit of an international researcher and $500 towards visitors from Australia. As part of the program, visitors are encouraged to give departmental colloquia.

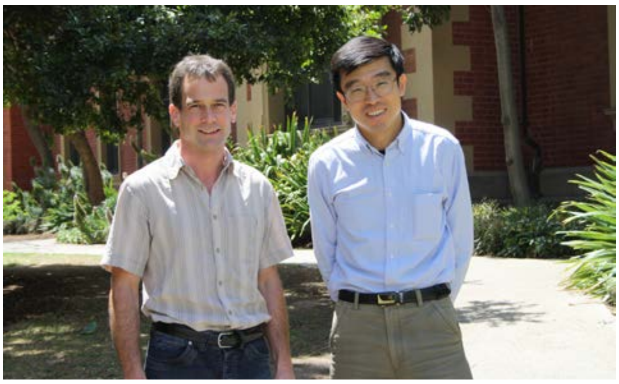
In 2012 the MMI funded visits by international scholars from the USA, Ireland and France.

From 12 to 22 January, Prof David Awschalom, a condensed matter physicist from the University of California Santa Barbara, visited the University and the MMI, as a Miegunyah Fellow. The Miegunyah Distinguished Visiting Fellowship Program was established by the University in 1993 on the recommendation of the Russell and Mab Grimwade Miegunyah Fund Committee. Each year, Deans of faculties and graduate schools are encouraged to nominate academics residing outside Australia, of international distinction in a field of interest to the University

Prof Awschalom gave a presentation at the Harvard-MMI Diamond Photonics Symposium as well as a departmental seminar and a well-attended public lecture. Prof Awschalom explained to an audience of over 200 attendees how the quantum properties of materials like diamond might revolutionise current electronics. Prof Awschalom was interviewed on the University research talk show *Up Close*; a podcast of the interview is available online (see 'Media' section). During his time at the University, Prof Awschalom met with several researchers and new areas of collaboration have been agreed upon, including sharing materials samples for further research.

In March, the MMI co-hosted and co-funded a visit by Dr Robert Miller from the IBM Almaden Research Lab, in collaboration with Prof Greg Qiao and the Melbourne Engineering Research Institute. During his two-week visit Dr Miller gave a University-wide seminar covering the broad range of materials research at IBM, as an entry to research collaboration opportunities. He met with researchers from across the University (Engineering, Science, and Medicine, Dentistry and Health Sciences) and attended a roundtable discussion hosted by the MMI about collaboration opportunities.

From 16 to 30 August, the MMI hosted a 10-day visit by Prof Kenneth Dawson, Director of the Centre for BioNano Interactions (CBNI), University College Dublin, Ireland. The aim of this visit was to build collaborative opportunities with the CBNI. Prof Dawson leads a number of European research projects and advises the Australian Therapeutic Goods Authority on nanomedicines. During his visit he gave a plenary talk at the MMI annual research workshop and presentations at the Department of Pharmacology, Bio21,



Dr Xavier Sauvage (CNRS, University of Rouen, France, left) with University collaborator Prof Xenong Xia (Mechanical Engineering).

the Bionics Institute as well as a MERIT seminar. Prof Dawson has participated in a discussion about a proposed Centre of Excellence in nanoengineered materials for biological systems and possible collaboration opportunities with the CBNI, and access to European funding.

The MMI and the Melbourne School of Engineering supported a visit, from 6 to 17 November, by Dr Xavier Sauvage. Dr Sauvage, from the Materials Physics Group, CNRS (National Center for Scientific Research) at the University of Rouen in France, is developing a collaboration with Prof Kenong Xia (Mechanical Engineering) in the high-resolution (atomic scale) chemical analysis of complicated alloys. Prof Xia has previously visited Dr Sauvage's laboratory and used its state-of-the-art characterisation facilities. During his visit, Dr Sauvage met with University researchers and gave a departmental seminar.

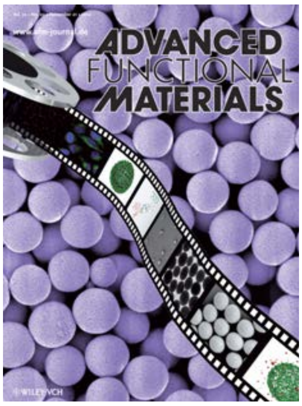
Event support

The MMI offers financial support for workshops, seminars and other materials-related events for up to $5 000 per workshop. Administrative support may also be provided.

The MMI sponsored the Australian Industry Group 2012 Technology Summit, held on 16 October. The MMI was represented by Materials for energy Theme Leader Dr David Jones, who spoke about the low cost, high volume solar cells, and by Director Steven Prawer, who chaired a session on "technology trends and the next big thing". The MMI specifically sponsored the final session of the summit, a wrap-up by conference MC Kerry O'Brien, on setting economic priorities.

The MMI provided $15 500 to support the third 'Emerging/Future Leadership Workshops - Australia-Japan Colloid Materials Partnership', held from 2 to 4 December. This allowance includes $5 000 each from the Materials processing and Materials for medicine theme leaders, who were allocated $20 000 each by the MMI to support research in their respective theme. Twenty-five emerging leaders interacted with 13 senior leaders, developing collaborations that offer scope for joint research grant applications to the Australian Research Council, the Japan Society for the Promotion of Science, and other government and industrial sources in both countries.

Some participants of the 'Emerging/Future Leadership Workshops - Australia-Japan Colloid Materials Partnership' supported by the MMI. From left to right: Dr Shigenori Fujikawa, International Institute for Carbon Neutral Energy Research, Kyushu University, Japan; Dr Jun Nakanishi, National Institute of Materials Science,Tsukuba, Japan; Dr Georgina Such, Chemical and Biomolecular Engineering; Prof Peter Scales, Chemical and Biomolecular Engineering; Dr Carolina Tallon, Chemical and Biomolecular Engineering.



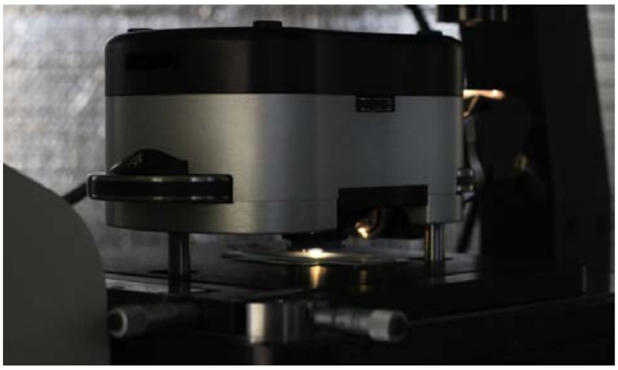
Publication cost support

The MMI recognises excellent materials research outcomes by contributing up to $1 000 towards the costs associated with the publication of cover articles. In return, the Institute requests the right to use the cover image in communications materials. In 2012, the MMI supported publication costs in seven journals (see back cover of this report).

2012 in review

Equipment access

Amongst the initiatives aiming to increase interdisciplinary collaboration within the University, the MMI launched the Platform Development Pilot Program (PDPP) and the MCN Access Scheme .



An Asylum Research MFP-3d AFM integrated with a fluorescence inverted microscope used for materials characterisation as well as imaging biological samples.Credit: Marta Redrado.

Platform Development Pilot Program

This two-year program started in March 2012 aims to optimise the use and access of research equipment at the University. In partnership with the Research Infrastructure Strategy Office and the Melbourne School of Engineering, the Institute aims to demonstrate that the PDPP is a working model for shared research infrastructure support and access.

Two platforms have been currently established and offer Nanomaterials Characterisation (NC) and Advanced Fluorescence Imaging (AFI) capabilities. A/Prof Ray Dagastine and Dr Angus Johnston (both from the Dept of Chemical and Biomolecular Engineering) have been appointed to lead the NC and AFI platforms respectively, assisted by Platform Support Officers Marta Redrado Notivoli and Benjamin Hibbs. A/Prof Dagastine and Dr Johnston provide the academic leadership to connect the disparate infrastructure across the University, to open it up to a wider user base and to enable greater collaboration between researchers.

For more information on the PDPP, go to p49 or visit www.materials.unimelb.edu.au.

MCN

Melbourne Centre for Nanofabrication

MCN Access scheme

The MMI launched the MCN Access Scheme in June 2012 in order to facilitate access to the Melbourne Centre for Nanofabrication (MCN). The scheme enables researchers from the University of Melbourne to access the MCN facilities at reduced rates. Two options are available to University researchers: 'pre-paid time', where users receive a 30% discount on usage costs and a 'merit-based application' which provides a period of free access to new users or researchers making new use of MCN equipment. The latter is granted by way of application and selection by the UoM-MCN User Group Committee.

Thanks to this scheme and the support of two technology fellows from the University appointed by the MCN, the usage of MCN facilities by the University has increased dramatically from an average of five hours a month to well over 60.

Conducting the engagement between the University and the MCN through the User Group Committee has resulted in a wider-reaching and transparent process.

For more information, go to p51 or visit our website.

Linkages and partnerships

External engagement is a priority for the MMI. The Institute places a high value on creating linkages to leverage strengths, increase research capacities, accelerate commercialisation and respond to global medical, environmental and energy challenges. In 2012, the MMI furthered its engagement with existing partners and paved the way for future partnerships with industry and government organisations in Australia and beyond.

Australian Industry Group

Engagement by the MMI with the Australian Industry Group (Ai Group)has increased the interaction between University of Melbourne researchers and Australian businesses, providing opportunities for materials research to contribute to Australian industry innovation.

The MMI sponsored the Australian Industry Group 2012 Technology Summit, held on 16 October (see 'Event support' section). The summit featured keynote talks from CEOs of major Australian and international businesses including Ai Group, Ericsson, Gartner and Hills Holdings.

BVA

Bionic Vision Australia (BVA) is a national consortium of world-leading Australian research institutions collaborating to develop an advanced retinal prosthesis, or bionic eye, to restore sight to people with serious vision impairment due to retinal disease. As a member in the BVA consortium, the MMI's role is to produce a fully biocompatible diamond electrode array that will be used to stimulate the optic nerve

The MMI has brought together physicists and engineers in the design and development as well as appointed three post-doctoral fellows to help solve the problems of fabrication, encapsulation, integration and testing. The successful implantation by BVA of Australia's first implant of an early prototype bionic eye was a milestone achievement shared with the MMI.

Lockheed Martin

The MMI, in conjunction with the Pro Vice-Chancellor (Research Partnerships) and the Melbourne Neuroscience Institute, hosted a visit by a delegation from Lockheed Martin on 13 November. The delegation of five from Australia and the US was led by Lockheed Martin Chief Scientist, Dr Ned Allen, and included the Senior Manager for Technology Initiatives.

The delegation undertook a capability and exploratory visit to better understand Australian R&D capabilities in areas including quantum and X-ray physics and advanced smart materials, and the links between bio and neuro research with simulation technology. The delegation members met with researchers in Physics, Electrical and Electronic Engineering, Computer Science, Neuroscience and the Pro-Vice-Chancellor (Research Partnerships), who hosted a discussion over lunch. Follow-up discussions will determine opportunities and interest for collaboration.

US Air Force Office of Scientific Research

The MMI director made a presentation to a visiting delegation of the US AFOSR (Air Force Office of Scientific Research) on 20 September. Extending our linkages with the US funding agencies is an important potential source of alternative future funding for materials-related research. To date, one grant offer has been received.

2012 in review

Events, outreach and communications

Through a diverse program of events, the MMI provides opportunities for researchers from the University and beyond to meet, mingle and share ideas as well as to be informed about the latest advances in the infrastructure that enables their research. In addition, the Institute holds public events to communicate developments in materials science to the general public and to encourage discussion on their impact on society.

MMI function after public event. Credit: Casamento Photography.

Research events

Harvard-MMI Diamond Photonics Symposium

Harvard University and the Melbourne Materials Institute held a joint Symposium on diamond photonics from 17 to 20 January. The Symposium brought together over 40 experts from around the world to discuss advanced fabrication techniques, sensors and imaging, photonics and plasmonics and nanodiamonds. With participants from universities in Australia, the UK, the US, Canada and Germany and industry members including Hewlett-Packard Labs (US) and Element Six (UK), new research collaborations were formed and existing collaborations extended. Funding for the Symposium was contributed by the Harvard University Australian Studies Committee, the US Air Force Office of Scientific Research, the journal Nature Photonics, the Harvard Quantum Optics Center and the MMI.

Participants of the Harvard-MMI Diamond Photonics Symposium (17-20 January).

Research workshop

On 20 August the MMI held its third annual research workshop. The workshop brought together over 100 researchers from the University and collaborating organisations, including the O'Brien Institute, CSIRO, Museum Victoria, the Reserve Bank of Australia and the National Gallery of Victoria. Prof Kenneth Dawson, Director of the Centre for BioNano Interactions, Ireland, gave the plenary talk. Twelve speakers presented on research in the areas of materials processing, materials conservation, energy, drug and vaccine delivery, quantum and nanophotonic materials, and tissue engineering. Forty-five students from the Master of Cultural Materials Conservation attended the workshop as part of their coursework.

Speakers and guests of the MMI materials research workshop (20 August) mingling betwen sessions.

Speakers and guests of the 'Materials Q&A' Wine & Cheese Afternoon (29 June) after the presentation.

Wine & Cheese Afternoons

Wine & Cheese Afternoons are informal networking events aiming to foster interdisciplinary discussion. The events typically consist of a 20 minute presentation on a topic of interest to the research community, followed by informal discussions over drinks and finger food.

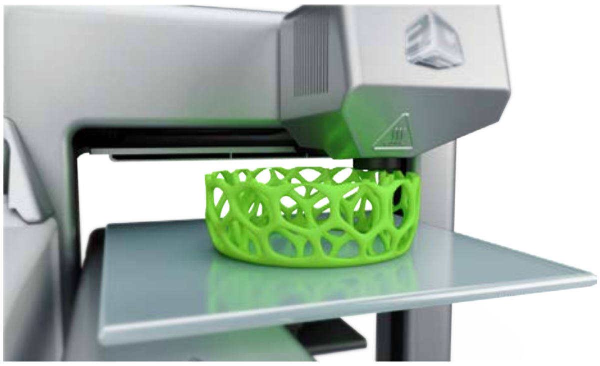
In 2012, the Institute held three Wine & Cheese Afternoons, each attended by 35 to 50 people:

- 'Mind the Gap: Increasing the Impact of Research - Tapping the world's greatest knowledge network' by Andrew Jaspan, co-founder of The Conversation on Thursday 22 March. Mr Jaspan shared his thoughts on bridging the gap between research and application, and the role trusted journalism plays in this.
- 'Materials Q&A' by Dr Daniel McDonald (Dept of Mechanical Engineering), Dr Annie Yan (Dept of Chemical and Biomolecular Engineering) and Dr Laurens Willems van Beveren, (School of Physics) on Friday 29 June. Dr McDonald, Dr Yan and Dr Willems van Beveren each presented a problematic aspect of their research and sought insights from the audience. The speakers received helpful suggestions from experts in their fields and beyond.
- 'The Future of Research at the University of Melbourne' by Prof James McCluskey, Deputy Vice Chancellor (Research) on Wednesday 24 October. The DVC(R) presented present key elements of the University research strategy outlined in *Research at Melbourne: ensuring excellence and impact to 2025.*

Technical Seminar Series

Launched at the end of 2011, the Technical Seminar Series provides an opportunity for students, researchers and professional staff in technical roles to learn about new equipment and discuss issues. The Series continued in 2012 with seven seminars held on the following dates and topics:

- 28 February: 'Dry pump technology' by James Carter from John Morris Scientific
- 20 March: '3D printing – rapid prototyping' by Travis Hardy from 3D Systems
- 20 April: 'The Melbourne Centre for Nanofabrication' by MCN Director Dwayne Kirk and two MCN instrument managers, with a additional input from A/Prof Ray Dagastine (Dept of Chemical and Biomolecular Engineering), an MCN Fellow.
- 30 May: 'Force sensing and surface imaging ' by Christian Löbbe from Scitech
- 26 September: 'Thermometric titration' by Carlo Chiara from MEP Instruments
- 23 October: 'Hydrogen generation' by Gabor Szirbik from Thales Nano
- 20 November: 'High-resolution cameras' by Antoine Varagnat, from Andor Technologies.



3D printer. Imagec ourtesy of 3D Systems.

2012 in review

MMI public lecture audience. Credit: Casamento Photography.

Public events

The Institute furthered its engagement with the general public by holding three well-attended public lectures on quantum materials, medical bionics and cultural materials conservation. Audio and video recordings are available on the MMI website.

As part of his visit to the University as a Miegunyah Fellow, Prof David Awschalom gave a lecture on 18 January. Entitled 'Engaging diamonds in the quantum age', the lecture focused on the potential of the quantum properties of materials like diamond to revolutionise current electronics. The talk was very well-attended, with a theatre overflowing with over 200 attendees.

On 5 July, the MMI held 'Medical bionics: how far can we and should we go?', a public lecture on the advancement of bionic devices and its implications on the individual and on society. Prof Rob Shepherd (Bionics Institute) related the history of bionic devices and provided an overview of available and trialled devices as well as a glimpse into future technologies and treatments. Andrew Alexandra (Centre for Applied Philosophy and Public Ethics) examined the social, philosophical and ethical questions raised by bionics and presented the range of views expressed in the 'therapy *versus* enhancement' debate. In a poignant testimony, Annette Watson, a recipient of a deep brain stimulation (DBS) device used to treat essential tremor, shared her story and recounted how the implant has improved her quality of life. The event attracted an audience of over 120 attendees.

On 25 October, the MMI and the Centre for Cultural Materials Conservation (CCMC), in partnership with Murrup Barak (Melbourne Institute for Indigenous Development) and the Warmun Art Centre held a public lecture entitled 'The science of conserving Gija art: How Indigenous and Western knowledge systems come together'.

Following the conservation work done by the CCMC on the significant Warmun Community Art Collection after it was damaged by floods in March 2010, A/Prof Robyn Sloggett discussed the importance of incorporating Gija indigenous knowledge into university-based research and training in art conservation. Complementing this perspective with a scientific approach, Dr Petronella Nel gave an overview of the current techniques used to analyse cultural materials, with a particular focus on understanding the composition of earth-based pigments. In an interview recorded for the occasion, artists from the Warmun Art Centre spoke about the significance of the Warmun Community Art Collection for the Gija people and the central place of art in their lives. A diverse and enthusiastic audience attended.

Above: Prof Awschalom giving a public lecture on the potential of the quantum properties of diamond for future electronics. Credit: Casamento Photography.

Facing page, top: Prof Steven Prawer, Prof David Awschalom and Prof David Jamieson. Credit: Casamento Photography.

Facing page, centre: Prof Rob Shepherd (Bionics Institute), Ms Annette Watson (DBS device recipient), Mr Andrew Alexandra (CAPPE), Prof Peter Scales (MC).

Facing page, bottom: Dr Petronella Nel presenting on the analyis of natural pigments as part of the public lecture on Gija art conservation.

Above, from left to right: Dr Katharina Ladewig, Dr Jessica Kvansakul and Dr Kate Fox at 'Science meets Parliament' (17,18 October). Credit: L. Sim.

Outreach

Dr Kate Fox, a researcher involved in the bionic eye project, has been very active in promoting the MMI and Bionic Vision Australia (BVA) externally. Dr Fox's outreach initiatives included conducting tours of the MMI-BVA facilities at the School of Physics for Year 10 students as part of the 'Growing Tall Poppies Project' and to University students from the Study Abroad and Exchange program. She also held a session on the bionic eye for 20 young Australians students in a visit organised by the Residential Indigenous Science Experience.

On 17 and 18 October, Dr Fox attended the annual 'Science meets Parliament' event, with Dr Katharina Ladewig (Dept of Chemical and Biomolecular Engineering), Dr Jessica Kvansakul (School of Physics) and Dr Deborah King (Dept of Mathematics and Statistics). Held annually, this two-day event is an opportunity for Australian scientists to meet parliamentarians in Canberra, share their hopes and concerns for Australian science and inform the research agenda. Dr Fox raised the issue of the retention of women in science, while German-born Dr Ladewig was quizzed about energy production in Europe.

Communications

Placing a strong focus on internal and external communications, the MMI launched its new website and quarterly eNewsletter in February. The quarterly eNewsletter informs MMI affiliates of relevant news and events and showcases the work done in materials science at the University. For more information, visit the MMI website.

2012 in review

Achievements and awards

The achievements of the University materials research community are many and varied. Captured here are highlights recognising some of the excellence and expertise demonstrated in 2012.

Prof Frank Caruso (Dept of Chemical and Biomolecular Engineering and MMI theme leader) was selected as the recipient for the Asia/Pacific region ACS Nano Lectureship Awards. ACS Nano Lectureship Awards honour the contributions of scientists whose work has significantly impacted the fields of nanoscience and nanotechnology.

Prof Robin Batterham was recognised as one of Australia's 100 most influential engineers. Former Chief Scientist of Australia, Prof Batterham is President of the Australian Academy of Technological Sciences and Engineering (Chemical Engineer) and a Kernot Professor in the Department of Chemical and Biomolecular Engineering. He is also a member of the MMI Advisory Board.

Internationally recognised chemist Prof Andrew Holmes was the recipient of one of only three Royal Medals awarded annually (UK). Also known as the Queen's Medals, they are awarded annually for the most important contributions in the physical, biological and applied and interdisciplinary sciences.

Prof Frank Caruso was awarded the 2012 Royal Society of Victoria Medal for Excellence in Scientific Research in the Physical Sciences to in recognition of his outstanding work in the fields of nanoscience and nanotechnology.

Prof Andrew Holmes AM receives his 2012 Royal Medal from Dame Jean Thomas DBE, Vice-President of the Royal Society. Credit: Royal Society.

Dr Penny Allen examining Ms Dianne Ashworth's eye.
Credit: BVA / D. Mirabella.

Dr Nicole Tse was awarded an Endeavour Executive Award for her project with the National Museum of the Philippines entitled 'Scoping cultural materials methodologies for works of art in the Philippines'.

Bionic Vision Australia (BVA) researchers successfully performed the first implantation of an early prototype bionic eye in three patients with *retinitis pigmentosa*. This marked a major milestone in BVA's development of a bionic eye and provided validation of the technology behind the retinal implant.

PhD Candidate and BVA team member Samantha Lichter won the second prize of the 3 Minute Thesis competition for her presentation on the bionic eye 'Carats that really improve your eyesight: an all diamond Bionic Eye'.

A group of Australian and British researchers created the first qubit based on a single atom in silicon. The team used a microwave field to control the spin of an electron bound to a single atom in order to read and write information. This work is a significant step towards the development of quantum computers and was published in the Nature.

Research fellow Dr Carolina Tallon was a national finalist in the 2012 Fresh Science program for her work developing ceramics capable of withstanding very high temperatures. These ceramics could enable jet travel at faster than the speed of sound and reduce the flight time between Melbourne and London to two hours.

ARC outcomes

ARC Federation Fellow Prof Frank Caruso was awarded an Australian Laureate Fellowship for 2012 by the Australian Research Council (ARC). The prestigious Fellowships are granted to outstanding world-class researchers who play a significant leadership and mentoring role in building Australia's internationally competitive research capacity.

Fourteen materials science projects from the University of Melbourne have received funding from the ARC as part of the Future Fellows, Discovery Early Career Researcher Award (DECRA), Discovery Projects (DP) and Linkage Infrastructure, Equipment and Facilities (LIEF) schemes, totalling $6 519 915.

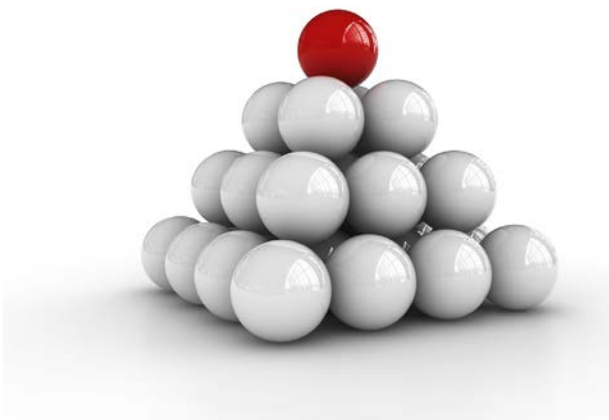
Dr Georgina Such and Dr Xuehua Zhang (both from the Dept of Chemical and Biomolecular Engineering) have been successful in the highly competitive Future Fellowships scheme. The grant will enable Dr Such to synthestise 'smart' polymeric materials for healthcare purposes, and Dr Zhang to engineer novel nano-sheet-based structures for advanced development of high sensitivity detectors, efficient energy conversion and storage devices.

Six materials scientists were granted a DECRA to carry out projects in areas ranging from geo-polymer cements to diamond cybernetics. The recipients of this very selective scheme are:

- Dr Igor Aharonovich (Physics), Fabrication strategies for nanophotonic devices;
- Dr David J Garrett (Physics), Diamond cybernetics: nanocrystalline diamond for interfacing;
- Dr Jiao Lin (Physics), Tailoring light with advanced plasmonic devices;
- Dr Christopher Ritchie (Chemistry), Rational design and fabrication of polyoxometalate based nanodevices;
- Dr Claire White (Chemical and Biomolecular Engineering), Nanoengineering of low-CO_2 geopolymer cements;
- Dr Yan Yan (Chemical and Biomolecular Engineering), Cellular dynamics of nanoengineered particles.

Four teams of senior materials researchers were awarded DP grants:

- Prof Frank Caruso and Prof Greg Qiao (both from Chemical and Biomolecular Engineering), Development of next-generation nanoengineered advanced materials for targeted applications;



- Prof Paul Mulvaney and Prof John Sader (resp. from Bio21 Institute and Mathematics and Statistics), Quantum dot energy transfer: the chemistry of blinking;
- Prof Carl Schiesser and Prof Peter R. Taylor (resp. from Chemistry and Victorian Life Sciences Computation Initiative), Developing and applying free radical quantum dots and diamonds: improving the performance of modern artists' paint;
- Prof Paul Webley and Dr Zhe Liu (both from Chemical and Biomolecular Engineering), Advanced adsorbents for gas separations.

Finally, two University aplications for materials science related infrastructure funding have been successful as part of the LIEF scheme. A group led by Prof Stan Skafidas received funds for the purchase of a helium and neon ion microscope. This instrument will complement existing infrastructure in high resolution microscopy, enabling users to image, measure, build and design complex nanostructures at the atomic level and upwards. A group headed by A/Prof Peter Lee was granted the funds to acquire a multi-scale imaging and characterisation facility that will allow researchers to study the micro and nanoscale structures and function of cells, tissues and organs.

2012 in review

Media

The work of materials scientists from the University of Melbourne was featured across a range of University, mainstream and specialist media. The following is a selection of media mentions; links to each item are available in the 'Media mentions' section of our website.

Prof David Awschalom. Credit: Casamento Photography.

Miegunyah Fellow Prof David Awschalom (University of California Santa Barbara) was interviewed on *Up Close*, the University of Melbourne's research talk show. Prof Awschalom discussed the powerful potential of quantum computing, and how materials such as diamond play a crucial role in the development of this emerging technology (episode 180: 'Diamond data mining: Quantum computing and the materials that make it possible').

Research Fellow Dr Jiri Cervenka, explained in *The Conversation* why graphene's electrical, thermal and mechanical properties make it a most promising material to revolutionise electronics and a potential component for improved airplane parts, electrical batteries, textiles and water filtration (19 March, 'Harder than diamond, stronger than steel, super conductor … graphene's unreal').

The research of Prof Frank Caruso's multidisciplinary team into therapeutic applications of nanoparticles was featured in *Science Magazine*, in an article reviewing the latest advances in nanotechnology-based tools and treatments worldwide (6 July, 'Prognosis for Nanotechnology Treatments').

The work of Prof Caruso and his colleagues from the Bionics Institute on the use of nanoengineered particles to deliver nerve survival factors to damaged hair cells of the inner ear was highlighted on ABC Science (25 September, 'Tiny particles target hearing loss').

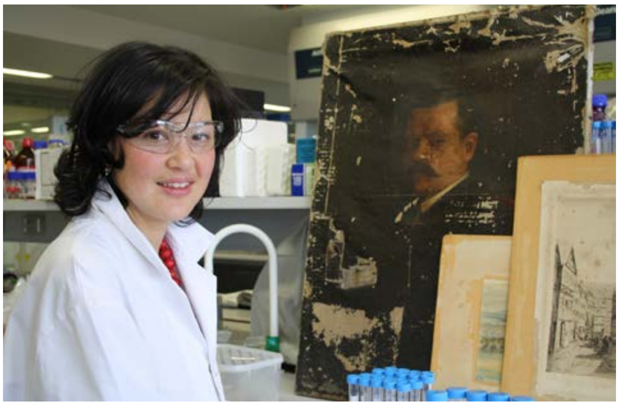
Centre for BioNano Interactions Director and MMI visitor Prof Kenneth Dawson (University College Dublin) was interviewed on *Up Close*. Prof Dawson discussed current research into nanoparticles and their potential effects on our health (episode 214 , 'Toxic titbits? The effects of nanoparticles on our health').

Dr Carolina Tallon's work on ceramics capable of withstanding very high temperatures was featured in *The Age* (25 October, 'The secret to two-hour flights to London: ceramics').

The *Melbourne Newsroom* reported on a new sieve to capture carbon dioxide developed by Prof Paul Webley and his colleagues (7 November, 'Capturing carbon with clever trapdoors').

Senior Postdoctoral Research Fellow, Dr Laurens Willems van Beveren (School of Physics) reported in *The Conversation* on his work to harness some of the less-well-known material properties of diamond in order to, hopefully, develop the next generation of transistors (8 November, 'More than a gemstone: using diamond for next-gen electronics').

Dr Tallon's work on ceramics capable of sustaining very high temperatures could be the secret to signanficantly shorter long-distance flights.



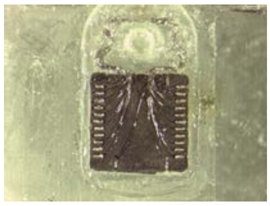
Ms Caroline Kyi in the Schiesser Group Laboratories, Bio21 Molecular Science and Biotechnology Institute.

Prof Stan Skafidas and Prof Frank Caruso featured in *The Age Melbourne Magazine*'s annual list of Melbourne's 100 most influential, inspirational, provocative and creative people for their work, respectively on a new genetic test for autism and nano-engineered particles to deliver more effectively lifesaving drugs (30 November).

Dr Angus Johnston and Prof Frank Caruso (Dept of Chemical and Biomolecular Engineering) were featured in an episode of *Visions*, the University's fortnightly video magazine. They explained how a recently acquired 'super high resolution microscope' is enabling researchers to see at the molecular scale and will help understand how nanomaterials and cells interact (episode 51, 'Engineering The Big Picture ').

Chemistry professor Carl Schiesser and art conservator Caroline Kyi were interviewed on *Up Close*. Prof Schiesser and Ms Kyi discussed how understanding the effect of free radicals on pigment helps art galleries and museums preserve important works of art (episode 224: 'Radicals in the gallery: Scientists contend with nature's art vandals').

The progress of Bionic Vision Australia's bionic eye project was keenly followed by the media throughout the year, with intensified interest after the announcement of the successful first implantation of an early prototype bionic eye on 30 August. Amongst the numerous media mentions the project attracted, several have featured interviews with MMI researchers involved in the project.



One of BVA's high-acuity pre-clinical bionic eye prototypes. Credit: O. Burns (Bionics Institute).

Prof Steven Prawer was interviewed on Melbourne talkback radio station 3AW radio (*Breakfast with Ross and John*, 7 February) and gave a broad description of the project.

Prof Prawer was also featured in *The Age*. In this article, Prof Prawer discusses how diamond is made artificially and why it is an ideal material for nerve cell stimulation (7 February, 'Man-made diamonds could unlock bionic eye').

Research Fellow Dr David Garrett was a featured guest on Radio New Zealand. A professionally trained ballroom dancer turned high-end London caterer, Dr Garrett recounts how he became part of team working on a bionic eye prototype (1 June, *Nine To Noon*).

Dr Hamish Meffin (National ICT Australia) and Prof Steven Prawer were interviewed in Materials World. They explain how Bionic Vision Australia's bionic eye devices work, what patients will see, and how they use diamond to stimulate the retina (24 July, 'A real eye opener - diamonds for bionic eyes').

One month after the announcement of the successful implantation of an early prototype bionic eye, Postdoctoral Research Fellow Dr Kate Fox and PhD candidate Samantha Lichter spoke on the 3RRR science program *Einstein-a-Go-Go* about the next generation prototype they are currently working on (30 September).

MMI Director Prof Steven Prawer, was featured on Channel 7 current affairs program *Sunday Night*. (18 November 'A cure in sight').

Researcher profiles: Prof Marcus Pandy

Chair, Dept of Mechanical Engineering, Melbourne School of Engineering

"I believe the most significant developments will come in the form of improved methods for non-invasive assessment of musculoskeletal health at the cell and organ-systems levels."

How would you describe what you do?

The overall goal of my research is to apply experiments, theory and computation to improve the quality of assessment and understanding of musculoskeletal function in the normal, injured and diseased states. My past and present work is focused on two interrelated goals: first, to develop and validate new theoretical and computational tools for determining musculoskeletal forces; and second, to combine biomechanical experiments with computational modelling to quantify and explain musculoskeletal function during human locomotion.

What potential applications may result from your research?

A better understanding of muscle, ligament and joint function in human movement will lead to improved treatment outcomes for patients with neurological and musculoskeletal conditions such as osteoarthritis (joint disease), osteoporosis (bone loss), and cerebral palsy (muscle spasticity). For example, patient-specific models of the musculoskeletal system can be used to diagnose the biomechanical causes of gait abnormalities in children with cerebral palsy and to improve pre-operative planning of orthopaedic reconstructive surgeries.

What do you hope to achieve in the next few years?

A primary goal of my current and future work is to improve the quality of assessment and understanding of muscle and joint function in older adults with knee osteoarthritis. This is critical for understanding the pathogenesis of osteoarthritis and for developing strategies to alleviate joint pain.

In a recent clinical trial using MRI-based musculoskeletal models, my colleagues and I found that individuals with patellofemoral (knee-cap) arthritis walk with altered lower-limb muscle and joint contact forces compared with healthy control subjects. We plan to extend this work by integrating X-ray fluoroscopic measurements of knee-joint motion with patient-specific musculoskeletal modelling to obtain a more comprehensive understanding of joint function in people with knee osteoarthritis.

What significant developments do you see in your field of research in the next 5 to 10 years?

I believe the most significant developments will come in the form of improved methods for non-invasive assessment of musculoskeletal health at the cell and organ-systems levels. The application of new imaging methods such as X-ray fluoroscopy and dynamic MRI will enable dynamic joint motion to be measured non-invasively with sub-millimetre precision.

If you weren't a scientist, what would you do?

If I was not concerned with earning a living I would write.

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

Communication; compromise; trust.

What do you do in your free time?

When I am not working I spend time with my wife, Romana, and our two children, Anika and Olivia (9 and 7 years old, respectively). I also enjoy outdoor activities such as hiking, jogging and tennis.

Dr Petronella Nel

Lecturer, Centre for Cultural Materials Conservation, School of Historical and Philosophical Studies

"I would like to disrupt the fear some sections of society associate with learning science."

How would you describe what you do?

Teaching and research in the arena of cultural materials conservation, with a focus on identifying and characterising materials associated with cultural heritage.

What is the aim of your research?

The main aim of my research is to provide scientific information to aid the conservator in treating cultural heritage from a more informed position. For instance I identified a formulation change in an adhesive product, which compromises its long-term performance.

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

I wish to develop the arts-science nexus and, as a consequence, extend and enhance the field of cultural materials conservation. To understand the benefit of such an approach, one only needs to think about how scientific and technical lines of inquiry have contributed to our understanding of psychology for instance.

Tell us about one of the 'mysteries' you are currently trying to solve.

I wish to discover markers, which indicate when cellulose nitrate based materials will start to rapidly deteriorate.

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

My PhD involved working with both the School of Chemistry and Peter Mac. Currently my research involves collaboration between scientists, conservators, archaeologists and museum professionals. It has been important to access the strengths of my colleagues such as their ability to see the big picture, or to pay attention to details, or their expertise on a specific technique or discipline. All involved should be committed to the outcome, for instance a thesis or a publication. Effective collaboration is not hindered by personalities or politics but fostered by a respect for everyone's individual contribution and expertise brought to the outcome.

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

Science plays an immense role in society. It is getting to the stage where governments are encouraging more scientific literacy because we live in an increasingly technological world.

What would you like to see change in the Australian research landscape?

I would like to disrupt the fear some sections of society associate with learning science because their environment convinced them they are stupid. Changing such perceptions would build bridges between science and other disciplines, making true interdisciplinary research possible, and dramatically changing the Australian research landscape.

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

I would like to have the freedom to explore a range of disciplines.

Give us a few words you would like people to associate with you.

My family provided the following words for describing me: persistent, loyal, level-headed, trustworthy, hard working, organised, and initiative.

What is the personal achievement you are the most proud of?

Being a bushwalking group leader.

Mr Tim Henderson

MMI-CSIRO PhD scholarship recipient, Dept of Chemical and Biomolecular Engineering

"There's something very exciting about using the regenerative potential of the human body and biomaterials to produce new functioning organs."

What is your PhD on?

My project is on the development of a porous hydrogel (a porous jelly-like substance) to replicate the natural environment that supports cells in tissue, a scaffold material for cells, with a focus on optimising the physical properties of these scaffolds for cell culture and tissue engineering applications.

What potential applications may result from your research?

The hope is that the work carried out over the course of my PhD will help identify suitable physical and chemical properties of cellular scaffolds for use in tissue engineering and cell culture applications. Physical properties of cellular scaffolds have been shown to be of great importance for cell proliferation and differentiation; therefore optimising these properties is of significant interest.

What attracted you to your research field?

There's something very exciting about using the regenerative potential of the human body and biomaterials to produce new functioning organs. Although the field of tissue engineering has been very much overpromised since the advent of stem cell biology, I consider myself very fortunate to be involved in such an interesting and growing field.

What academic achievement you are the most proud of?

Being offered a PhD and receiving funding and support. Three years is a big investment and being identified as a suitable candidate to take on a PhD and the responsibilities that come with it was a great honour.

What do you hope to achieve in the next few years?

Ideally I would be delighted to graduate in the next few years. Once that's out of the way I suppose I will have to begin considering entering the work force. In the short term I would love the opportunity to work as a postdoc overseas, however a role in science policy has started to interest me.

What significant developments do you see in your field of research in the next 5 to 10 years?

The field of tissue engineering has been quite slow-moving; unfortunately I don't see engineered complex organs being commercially available for many years to come. It's hard to say when we will see a complex organ built form the ground up, but certainly if that is achieved in the next 10 years it would be a very significant development. I think there is quite a lot of promise in the use of animal organs to address the shortage in supply of many organs and I think we will see wide use of animal organs in humans before we see similar use of artificially constructed organs.

What do you think of the MMI-CSIRO scholarship program?

I think it's fantastic. The project that I am working on covers multiple disciplines requiring knowledge from a number of different areas. Having supervisors from both the University of Melbourne and the CSIRO not only provides a wider knowledge base but also has broadened the potential scope of my project.

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

During my PhD I've had the opportunity to familiarise myself with a 3D printer that we have in our lab. I think the use of 3D printing for rapid prototyping and other industrial uses holds great potential and would be an amazing field to be involved in as it develops. Again, the excitement of working with an up and coming technology is something that interests me.

MMI research themes: overview

Most materials research at the University of Melbourne is represented by the MMI under five themes. In 2012, the theme 'Materials conservation' was created, providing a more comprehensive picture of the scope of materials research at the University of Melbourne.

Materials conservation

Theme leader: A/Prof Robyn Sloggett, School of Historical and Philosophical Studies.

The research undertaken in this theme aims to evaluate conservation practices, develop new approaches to conservation and treatment, assess and respond to deterioration in cultural materials and provide advice to conservation professionals.

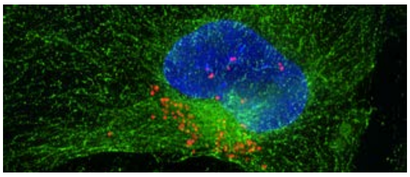
Materials for energy

Theme leader: Dr David Jones, School of Chemistry, Bio21 Institute.

The research represented in this theme explores new materials that enhance energy efficiency or provide more sustainable alternatives to existing energy-related technologies .

Materials for medicine

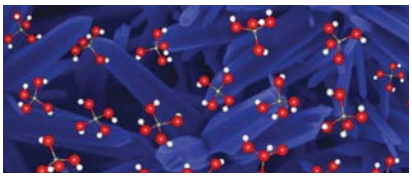
Theme leader: Prof Frank Caruso, Dept of Chemical and Biomolecular Engineering.



This theme explores the interactions between biological systems and engineered materials, focusing on developing material platforms to underpin advances in drug and gene delivery vehicles and tissue engineering scaffolds.

Materials processing

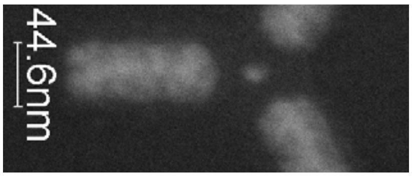
Theme leader: Prof Peter Scales, Dept of Chemical and Biomolecular Engineering.



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

Quantum and nanophotonic materials

Theme leader: A/Prof Ann Roberts, School of Physics.



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.

Materials conservation 2012 highlights

Theme leader

A/Prof Robyn Sloggett

Researchers

Prof Carl Scheisser, A/Prof Ann Roberts, A/Prof Robyn Sloggett, Dr Petronella Nel, Dr Russell Taylor, Dr Nicole Tse, Ms Stefanie Alexander, Mr Brook Andrew, Ms Paula Dredge, Ms Jennifer Dickens, Ms Jude Fraser, Ms Caroline Fry, Ms Melina Glasson, Ms Katy Glen, Ms Cushla Hill, Ms Holly Jones, Ms Vanessa Kowalski, Ms Caroline Kyi, Ms Deborah Lau, Ms Sophie Lewincamp, Ms Libby Melzer, Mr Mahmoud Mohammed, Ms Catherine Nunn, Ms Briony Pemberton, Ms Marcelle Scott, Mr Nicholas Selenitsch.

Associated institutions and research centres

ANKAAA (Association of Northern, Kimberley and Arnhem Aboriginal Artists), ANSTO (Australian Nuclear Science and Technology Organisation), Australian Research Council Centre of Excellence for Free Radical Chemistry and Biotechnology, Art Gallery of New South Wales, Artlab Australia, AusHeritage, Australian Synchrotron, Australian War Memorial, Balai Seni Visual Negara (BSVN: National Visual Arts Gallery, Malaysia), Centre for Classics & Archaeology, CSIRO, The Dax Centre, Ian Potter Museum of Art, International Conservation Services, Koorie Heritage Trust, Melbourne Institute for Indigenous Development Murrup Barak, Melbourne School of Engineering, Melbourne School of Land and Environment, Mulka Art Centre, National Gallery of Victoria, National Museum of the Philippines, NFSA (National Film and Sound Archive), Queensland Art Gallery | Gallery of Modern Art, RSL LifeCare, School of Chemistry, School of Earth Sciences, School of Physics, Secretariat for Culture Timor-Leste, Silpakorn University, Warmun Art Centre, Warringarri Arts, Western Australian Museum and Yackandandah Historical Society.

The newly created Materials conservation theme presents research activities relating to cultural materials conservation and brings together experts from the fields of art, art conservation, archeology, history, chemistry, earth sciences, physics and engineering. In 2012, the array of activities undertaken included convening international conferences, gaining a better understanding of 'temporal activity' of cultural materials in response to their environment and strengthening linkages across the University.

Events

An MMI-sponsored workshop was held in Melbourne in partnership with the Western Australian Museum (WAM) and Heritage Victoria from 18 to 22 June. Dr Ian MacLeod (WAM) delivered a five-day metals conservation workshop focusing on wet maritime archaeological items. Standard and test conservation methods were applied to a number of items, and research gaps were identified.

As part of the annual MMI materials research workshop, researchers from the Materials conservation theme presented case studies from recent work with Aboriginal communities that examined the role of materials science in building new research programs with Indigenous communities. This

Dr Ian MacLeod (Western Australian Museum) and Marcelle Scott (Centre for Cultural Materials Conservation) deconcreting iron corrosion products prior to further analysis and conservation at Heritage Victoria conservation labs. Credit: J. Walton.

session examined research projects where science validates Aboriginal knowledge and Aboriginal knowledge informs scientific inquiry.

Mr Julian Bickersteth, Director of International Conservation Services, led a workshop on 23 August on the development of evidence-based sustainability measures in cultural materials conservation.

An MMI public lecture, presented in collaboration with the School of Philosophical and Historical Studies on 25 October, the Murrup Barak Institute and Warmun Art Centre, showcased the links between Western scientific knowledge and traditional Aboriginal knowledge held by the Gija people at Warmun.

Dr Tse convened two international conferences: 'The Meaning of Materials in Modern and Contemporary Art' , held on 9 and10 December 2012 at the Queensland Art Gallery and 'The Conservation of Material Culture in Tropical Climates', held on 23-25 April at Silpakorn University, Thailand.

Update on seed-funded project

The MMI seed-funded project undertaken by Dr Nicole Tse and A/Prof Ann Roberts, 'Museum Collections, Climatic Conditions and Monitoring *in situ* Physical Changes ' aims to better understand the range of mechanical responses of an object to its surrounding environment, using a laser speckle sensor developed to measure 'temporal activity' or spatial data from the surface of historical artifacts.

Successes with dynamic speckle analysis in 2012 have monitored the 'temporal activity' from acrylic paints, bark painting support, paper based items and canvas paintings aged in varying environments and the effects of air conditioning and environmental changes on these items (see p44).

ARC submission

An ARC Discovery Project application will be submitted to undertake new research into the conservation of the buried metal objects from Gallipoli. This is an outcome of the June workshop held in partnership with the Western Australian Museum and Heritage Victoria.

The ANZAC Gallipoli Campaign is one of the most significant events in Australian, New Zealand and Turkish history. Bringing together cultural materials conservators and archaeologists and aligning to the 2015 centenary of the ANZAC Campaign, this proposed ARC project will present a unique opportunity for conservation materials scientists to be present on site during the excavation and to provide real time chemical, electrochemical and materials analyses of the artefacts and their burial environment. This iterative and interactive approach will provide the archaeologists with the best advice on how the microenvironment of the sites can be managed and interpreted.

Linkages

The Materials conservation theme has been effective in linking researchers with instrumentation on campus and continues to play an important role through the MMI in developing research capacity in this area.

Ngalangangpum School, Nancy Nodea. © Copyright in this artwork and text remains with the Artist and Warmun Art Centre respectively.

Materials for energy 2012 highlights

Theme leader

Dr David Jones

Researchers

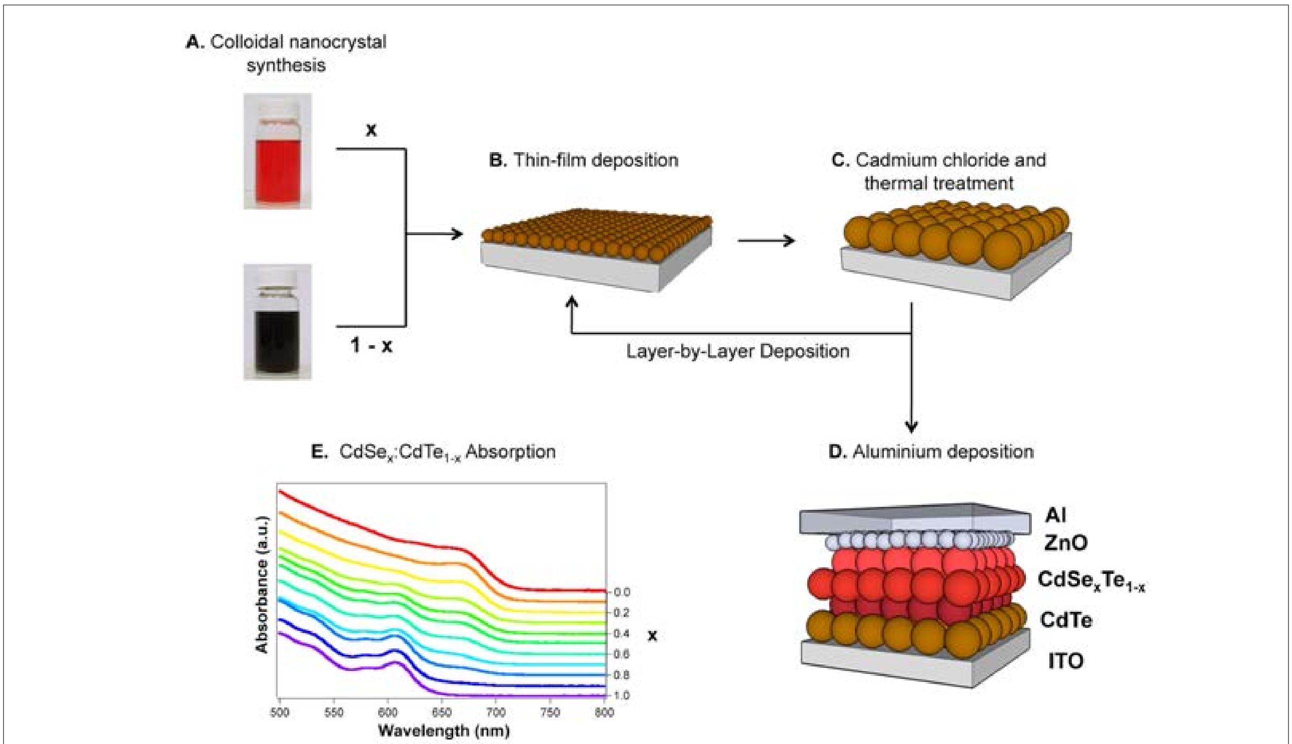
Prof George Franks, Prof Ken Ghiggino, Prof Lloyd Hollenberg, Prof Andy Holmes, Prof Paul Mulvaney, Prof John Sader, Prof Kenong Xia, A/Prof Rachel Caruso, A/Prof Ray Dagastine, Dr Dehong Chen, Dr David Jones, Dr Daniel McDonald, Dr Anthony Morfa, Dr Tich Lam Nguyen, Dr Carolina Tallon, Dr Xingzhan Wei,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

Associated research centres

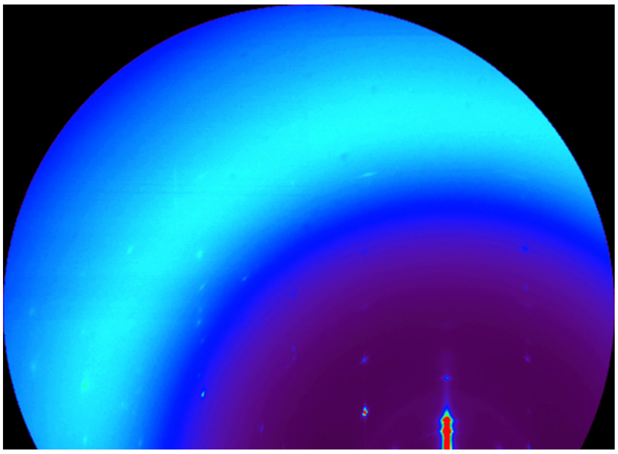
Advanced Porous Materials Group, Nanoparticle.com, Photophysics Research Group, the Holmes Group.

Nanocrystal photovoltaics

Chemists at the University of Melbourne and CSIRO have been working on nanocrystal photovoltaics. This is a new method for fabrication of solar cells that promises to drastically reduce production costs. They demonstrated in a recent *ACS Nano* paper that vectorial charge separation in alloy-based nanocrystal cells provides a method for improving photocurrent. The figure below shows the device structure composed of several layers of the semiconductors CdSe and CdS as light absorbers, ITO as the transparent conductor and aluminium as the counter electrode. The amount of solar spectrum absorbed by the semiconductor is tuned by varying the ratio of sulfur and selenium.



A schematic outline of the layer-by-layer process for making CdSe$_x$Te$_{1-x}$ nanocrystal solar cells. Published in *ACS Nano*, 2012,6, 7, 5995–6004.



UoM joins US-Australia Institute of Advanced Photovoltaics

The University of Melbourne (UoM), as a node in organic solar cells, has become part of the US-Australia Institute of Advanced Photovoltaics. The institute, directed by Prof Martin Green at the University of New South Wales, brings together traditional inorganic and the emerging organic solar cell technologies under one roof to interact with leading US research and industry partners. The eight-year, $33 million program will focus on over the horizon technologies that will transform solar cell technologies and improve efficiencies and reduce costs.

Printed organic solar cells

The Victorian Organic Solar Cell Consortium, directed by Prof Andrew Holmes at the University of Melbourne, has purchased three new printers to expand its operations. Organic solar cells can be printed using inks formulated from specialty polymers or organic molecules, designed and synthesised, at the University. Printing solar cells offers the potential to use commercial printing equipment to significantly lower the cost of solar cells. Significant improvements require developing new light-harvesting material, understanding their physical properties and controlling the self-organising processes, which occur on the nanometre to micrometre scale.

Left: X-ray diffraction pattern obtained at the Australian Synchrotron on one of Dr David Jones' team's new materials. Analysis of the pattern will allow determination of the processes involed in controlling the nano-scale organisation of the materials in printed solar cells.

Right: Printing solar cell electrodes as the first step in fully printed organic solar cells in the Victorian Organic Solar Cell Consortium, consortium. Credit: N. Clark.

Materials for medicine 2012 highlights

Theme leader

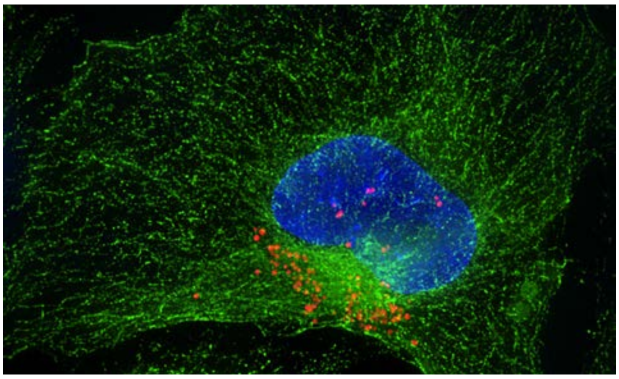
Prof Frank Caruso

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 Kwun Lun Cho, Dr Jiwei Cui, Dr Hirotaka Ejima, Dr Kumar Ganesan, Dr Angus Johnston, Dr Kristian Kempe, Dr Peck Ling Lee, Dr Hannah Lomas, Dr Markus Müllner, Dr Carrie Newbold, Dr Clem Powell, Dr John Provis, Dr Rob de Rose, Dr Gabriel da Silva, Dr Georgina Such, Dr Yajun Wang, Dr Yan Yan, Dr Zhiyuan Zhu, Ms Marloes Kamphius, Mr Ka Leo Noi.

Associated research centres

Austin Hospital, Baker IDI Heart and Diabetes Institute, Bio21 Institute, Bionics Institute, CSIRO Materials Science and Engineering, Monash Institute of Pharmaceutical Sciences, Particulate Fluids Processing Centre, Walter and Eliza Hall Institute.



Deconvolution microscopy image of HeLa cells internalising nanoengineered polymer particles. The nucleus is in blue, microtubules are in green and particles are in red. Credit: Y. Yan.

Novel responsive materials

The Nanostructured Interfaces and Materials Science (NIMS) Group led by Prof Caruso has embarked on research designing 'smart' materials, focusing on new approaches for the assembly and tuning of physicochemical properties. Single-step multilayered capsules have been generated via several approaches, including mussel-inspired dopamine polymerisation and photo-triggered continuous assembly. Novel fabrication and characterisation techniques have also been developed to control an array of physical parameters of materials, such as shape and rigidity. These materials will offer new possibilities to control the biological behaviour of materials.

Multicompartment materials

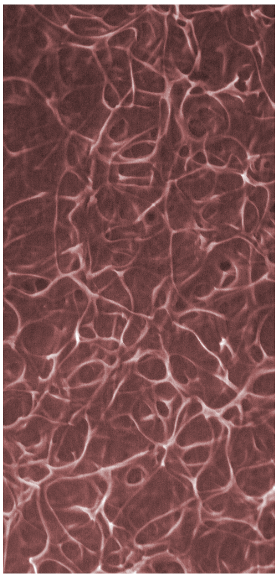
Equipping materials with multiple functionalities is highly desirable for sophisticated biological applications whereby synergistic interactions are often required for improving efficacy. To achieve these goals, Prof Caruso's group has continued to develop higher-ordered, nanoengineered structures through modular assembly of macromolecules. Polyrotaxanes, polymer brushes, liposomes and polymersomes have been explored as building blocks for generating novel materials with multiple functionalities.

Nano–bio interfaces

Understanding the cellular dynamics of nanoengineered materials is the cornerstone of improving materials design. To this end, Prof Caruso's team has explored new technologies to unravel these interactions by using super resolution optical microscopy and proteomics. Insights into how cells bind, internalise and degrade nanoengineered materials have been reported. The team has shown that the intracellular degradation of capsules can be fine-tuned through controlled cross-linking. The switch between cell surface binding and internalisation of capsules can be influenced by the choice of antibody functionalisation.

Designing biomaterials and bioreactors for soft tissue engineering

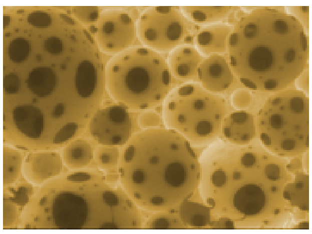
Tissue engineering has the potential to alleviate shortages of donor tissues and allow regeneration of a patient's tissues following cancer or trauma or to treat certain genetic defects. It aims to grow tissues, such as bone, fat and muscle, which replicate the properties of native tissue and integrate thoroughly into the patient's body to fulfil that particular tissue's role over the long-term. Despite this promise, relatively few tissue engineering processes have found clinical success to date. One key challenge in this field is to scale-up tissue growth to produce vascularised 3D tissues at the human scale. To tackle this, the Tissue Engineering Group led by A/Prof O'Connor is developing soft biomaterial scaffolds that encourage the desired cell and tissue growth by matching the key properties of the natural tissue. Stronger materials are used to design *in vivo* bioreactors, fabricated using 3D printing, for the tissue-specific stress regimes to protect tissue during development. The team has also developed microsphere delivery systems to provide long-term controlled release of multiple bioactive molecules to regulate inflammation and soft tissue growth *in vivo* for tissue engineering.



False-colour images of scanning electron microscopy reveals the highly porous internal structures of two different 3D hydrogels designed for cell culture.

Credit, left: T. Henderson, K. Ladewig, D. Haylock, K. McLean, A.O'Connor, University of Melbourne Advanced Microscopy Facility.

Credit, below: S. Leo, A. O'Connor, University of Melbourne Advanced Microscopy Facility.



Tailoring hierarchically porous materials for bioengineering applications

Hierarchical porosity in the mesopore to macropore range provides advantages in materials design for a range of engineering applications that can benefit from a combination of high surface areas and high throughput. In bioengineering applications, advanced materials are desirable to bind and release large macromolecules with tailored selectivity, capacity and kinetics. A/Prof O'Connor's team in collaboration with A/Prof Michelle Gee have designed a new class of hierarchically porous materials to overcome these limitations by using a co-micelle/emulsion templating (co-MET) route to engineer materials with both narrowly distributed mesopores for high surface area and large macropores for enhanced diffusion. Further control over solute uptake and release from such engineered porous materials has been achieved by tailoring both the physical architecture and the surface chemistry of the pores. Systems were designed for adsorption of proteins from solution and for controlled release of bioactive molecules over periods of weeks to months to enhance tissue engineering.

Polymer Science Group

The Polymer Science Group (PSG), led by Prof Qiao, focuses on the development of materials for medicine through innovative conception and sophisticated macromolecular engineering. Some of the recent work in the PSG involves the development of promising implantable drug-polymer conjugate devices, nanoparticle drug delivery vehicles and glycopeptide mimics for the treatment of cancer, and infectious and neurodegenerative diseases. Furthermore, the introduction of intricately structured materials, including nanocomposites, nanolenses, highly ordered nano and micro-porous films, and self-assembled polymers, are paving the way for exciting opportunities in advanced optics, lightweight and mechanically robust composites, nanoparticle-enhanced radiotherapy, imaging and separation sciences. The PSG builds upon the forefront of materials science to prepare a range of biomaterials (eg peptide based architectures, hydrogel scaffolds, biofilms) via strategic and novel methodologies (eg continuous assembly of polymers) for the next generation of targeted bioapplications.

Materials processing 2012 highlights

Theme leader

Prof Peter Scales

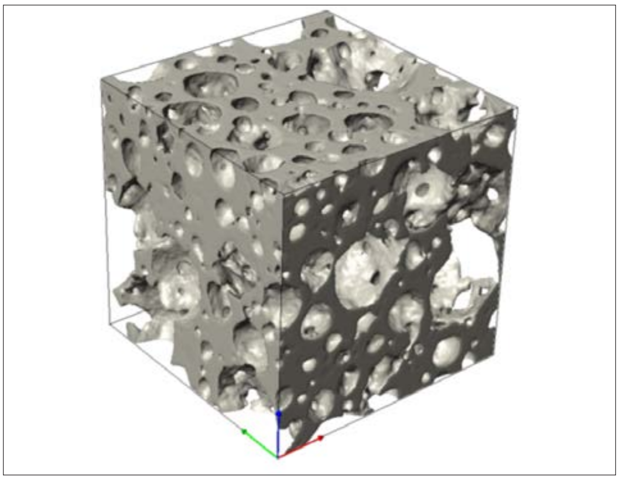
Researchers

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 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 (CRCCO2), ARC Special Research Centre for Particulate Fluids Processing, Defence Materials Technology Centre.

The Materials processing theme reflects the considerable overlap of engineering, science and mathematics in the MMI. Three diverse areas of focus are reflected in the research outputs. These include engineered products, materials separations and interfacial phenomena.



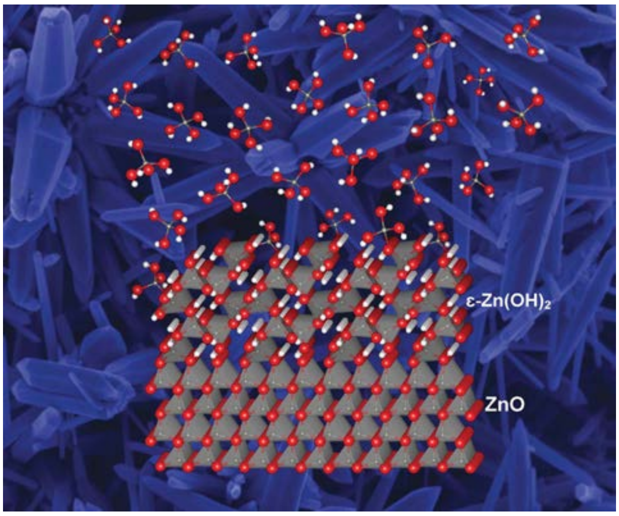
3D reconstruction of microstructure of zirconia ceramic foam captured by X-ray micro-tomography. Credit: C. Tallon, P. Mignone, M. Wang and G. Franks (unpublished work).

Engineered products

The control of the meso and/or macro-porous structure in materials is difficult due to the fact that structure at all but the micro or nano-scale is rarely controlled solely by atomic and molecular forces alone. Hydrodynamic forces as a result of shear are an important secondary consideration and the scaling of shear and processing to full scale is a key technological consideration in the production of engineered products. A good example is the production of ceramic foams. These foams have application in diverse areas, such as ultra high temperature insulation and bone tissue scaffolds. Significant advancements in our understanding of the forces between 'soft' or deformable surfaces along with our understanding of hydrodynamics have continued to underpin the production of engineered products. A highlight in the last year has been systems that include micellar and emulsion systems to produce hierarchically porous macro-spheres.

Material separations

Separation is critical to the processing of a large range of materials with gas, liquid and solid systems all being important. A key area of interest in the area of gas separations is the development of both low and high temperature membranes for gas separations as part of our considerable efforts in the sequestration of CO_2 as a precursor to storage or utilisation for greenhouse gas mitigation. Experimental measurements and molecular simulations of high temperature gas adsorption onto nanoporous carbon elucidate new approaches to separating and sequestering CO_2. Significant efforts in the past year have gone into validating processes and costs at Hazelwood power station (Victoria) to provide a platform for validation of the work on large scale. In solid-liquid systems, the role of shear and particle collision in the densification of flocculated aggregates has been the focus of a major study to understand the dynamics of such processes with the aim of better being able to predict thickening and filtration processes. These are the workhorse methodologies of the minerals industry for the recovery of water and dewatering of suspensions.



Schematic representation of the hydrothermal growth of zinc oxide crystal from solution via an intermediate layer of zinc hydroxide which transforms to oxide via primarily solid state transformation. Published in *Crystengcomm* 2012, 14, 1232-1240.

Interfacial phenomena

Understanding interfacial phenomena is key to nearly all of the work in the materials processing theme. It is critical to not only engineered products but separations as well. This includes food, consumer products, mineral processing, ceramics and wastes such as mineral tailings and waste water sludges. Once again, it is the balance of forces between atomic, molecular and hydrodynamic forces that controls materials processing and a range of new insights have been gained in the past year. Of particular interest is the interaction between soft surfaces and long range interactions between hydrophobic surfaces in water.

'Compound sessile drops'. Published in *Soft Matter 2012*, 8, 43, 11007–11194.

Quantum and nanophotonic materials 2012 highlights

Theme leader

A/Prof Ann Roberts

Researchers

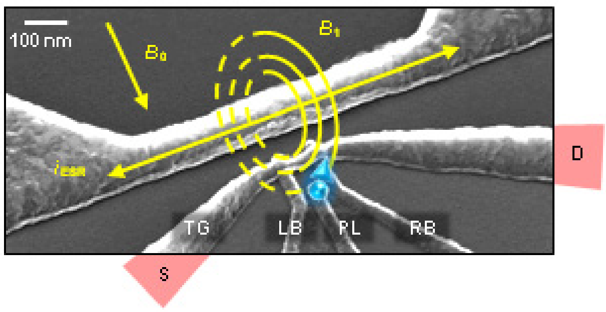
Prof Frank Caruso, Prof David Jamieson, Prof Fedor Jelezko (University of Ulm, Germany), Prof Lloyd Hollenberg, Prof Paul Mulvaney, Prof Steven Prawer, Prof Jorg Wrachtrup (University of Stuttgart, Germany), A/Prof Andy Greentree (RMIT), A/Prof Jeffrey McCallum, A/Prof Ann Roberts, A/Prof Robert Scholten, 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 Laurens Willems van Beveren, Dr Yan Yan, Dr Changyi Yang, Dr Shan Shan Kou, Dr Tim James, Dr Snjezana Tomljenovic-Hanic.

Associated research centres

Bio21 Institute, Centre for Coherent X-ray Science, Centre for Quantum Computation and Communication Technology, Micro-Analytical Research Centre (MARC), Melbourne Centre for Nanofabrication.

Ion implantation for qubit devices

A breakthrough made by a team working in the ARC Centre of Excellence for Quantum Computation and Communication Technology from the Universities of New South Wales and Melbourne shows that the scale of classical semiconductor devices is now small enough to control the quantum mechanical state of a single electron. Their device has been built with the standard tools of the semiconductor industry. It is configured with a single electron orbiting a single phosphorus atom that was engineered into the device by ion implantation in the laboratories of the School of Physics at the University of Melbourne and configured and measured with nanocircuitry engineered at the University of New South Wales. As reported in *Nature* [Pla et al., *Nature* 2012,489, 541-545,] this quantum state is remarkably long-lived, opening the possibility of quantum computing based on information encoded on single electrons built from silicon. This suggests a smooth path from the classical to the quantum domain to open new possibilities for information storage and processing based on bits encoded on electron spin.



Single-atom quantum bit device: Electron micrograph image of the qubit device. The light areas are metallic electrodes used to form a 'single-electron transistor'. The transistor is coupled to a single phosphorus atom (buried in the silicon chip) to read out that spin state of the atom. The microwave transmission line is shown in the upper left portion of the image. Published in *Nature* 2012, 489, 541–545.

Mesoscopic devices

In 2012, the low-temperature, high magnetic field laboratory conducted a series of experiments in the area of mesoscopic device physics. Initially, the superconducting properties of aluminium films and a niobium SQUID device were studied. The team subsequently investigated the electronic transport properties of integrated semiconductor nanowire devices and quantum dots, which form naturally in the sub-threshold regime of commercially available high-electron mobility transistors. Furthermore, the team have investigated the surface-conducting properties of hydrogen-terminated single-crystal diamond by magnetic field spectroscopy. Finally, ultrananocrystalline nanodiamond (UNCD) films grown by chemical vapour deposition were characterised as a function of temperature.

Nanophotonic materials and devices

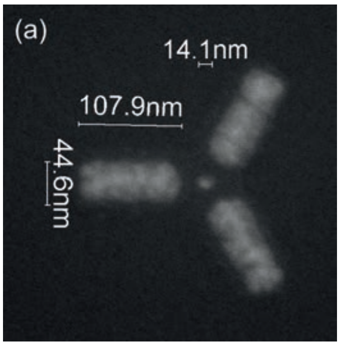
Researchers from Optical Physics and Bio21 have experimentally demonstrated ultra-compact plasmonic polarising devices. These take advantage of phase changes associated with resonances in nanoscale apertures in thin metallic films. In 2012 MSc student Jasper Cadusch demonstrated a 40nm thick plasmonic quarter waveplate fabricated using focused ion beam milling. In collaboration with Dr Tim Davis (CSIRO), research into optical antennas has also led to the fabrication of trimer nanoparticle arrays designed to host emitters (fig. (a)) and the demonstration of a nanoscale 'J-pole' antenna (fig. (b)). Research in this field makes extensive use of the outstanding facilities available at the Melbourne Centre for Nanofabrication.

Quantum decoherence detection

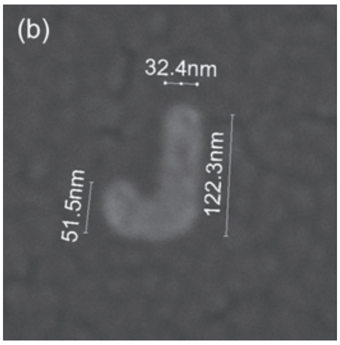
Following on from the ground-breaking work exploring the quantum properties of nanodiamonds in living cells published in *Nature Nanotechnology* in 2011, research groups from Physics, Genetics and Chemical and Biomolecular Engineering are looking at new ways to track cell evolution in the early embryonic model system, *Drosophila melanogaster,* the common fruit fly. The team has successfully introduced nanodiamonds into the complex embryo system and tracked their intracellular dynamics for the first time. This represents an exciting first step toward to unique cell identification and tracking.

Tracking of intrinsic fluorescent biomarkers in sunscreen

This collaborative project involves researchers from Physics, Bio21 and Chemical and Biomolecular Engineering. Zinc-oxide (ZnO) nanoparticles (NPs) and NP-derived thin films were synthesised at Bio21, NPs were added to skin cell culture produced in the Tissue Engineering lab and optically characterised at the School of Physics. The films and sunscreen samples demonstrated a high spatial density of bright optical defect centres. Skin cells with incorporated ZnO were also cultured and optically analysed with visible light with no added fluorescent tags.



Scanning electron microscope image of a triangular array of gold nanoparticles with a spot in the middle designed for hosting a collection of light emitters. The gold nanoparticles are able to provide optical feedback to the emitters leading to enhancements that could result in developing the world's smallest laser. Credit: D. Gomez / Z. Q. Teo.



SEM image of an optical 'J-pole' antenna. Credit: T. James.

Interdisciplinary Seed Funding scheme

Scheme

The Interdisciplinary Seed Funding (IDSF) scheme is run centrally by the Office of the Deputy Vice-Chancellor (Research) and the Melbourne Research Institutes. The scheme 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
- are consistent with the broad research objectives of one or more of the Melbourne Research Institutes or designated emerging areas of focus.

Selection process

The MMI consider all interdisciplinary proposals that align with one or more of the following research themes:

- Materials for medicine
- Quantum technologies
- Materials processing
- Materials conservation
- Bionic devices
- Defence materials
- Materials enabling convergence in cancer research.

Applications are ranked by a sub-group of the MMI's Management Committee or their delegates (see Interdisciplinary Seed Funding sub-committee below). These rankings determine the allocation of central funds by the Pro-Vice-Chancellor (Research Collaboration) and Melbourne Research Institute Directors. The MMI then funds a further four to six projects according to the ranking order. In 2012, six projects were granted $40 000 each by the MMI.

Selection committee

In 2011, the panel responsible for the selection of projects to be funded in 2012 was composed of: Prof George Franks, Prof Lloyd Hollenberg, Prof David Jamieson, Dr Daniel McDonald, Prof Richard O'Hair, Prof Damien Power, Prof Steven Prawer, Dr Georgina Such.

IDSF lunches

Each year the MMI invites seed-funded recipients from all funding rounds for a convivial lunch and an update on the progress of their projects. This event is also an opportunity for the MMI to receive feedback on the scheme and for recipients to learn about other projects and approaches to tackle interdisciplinary challenges.

2012 funded projects

The 2011-2012 seed-funding round attracted 21 applications in materials research. The projects submitted reflected well the interdisciplinarity nature of scheme, with applicants coming from 13 departments and four faculties, including collaborators from 11 external organisations. The top 10 ranked proposals were funded to a total of $400 000 from the MMI and University central fund .

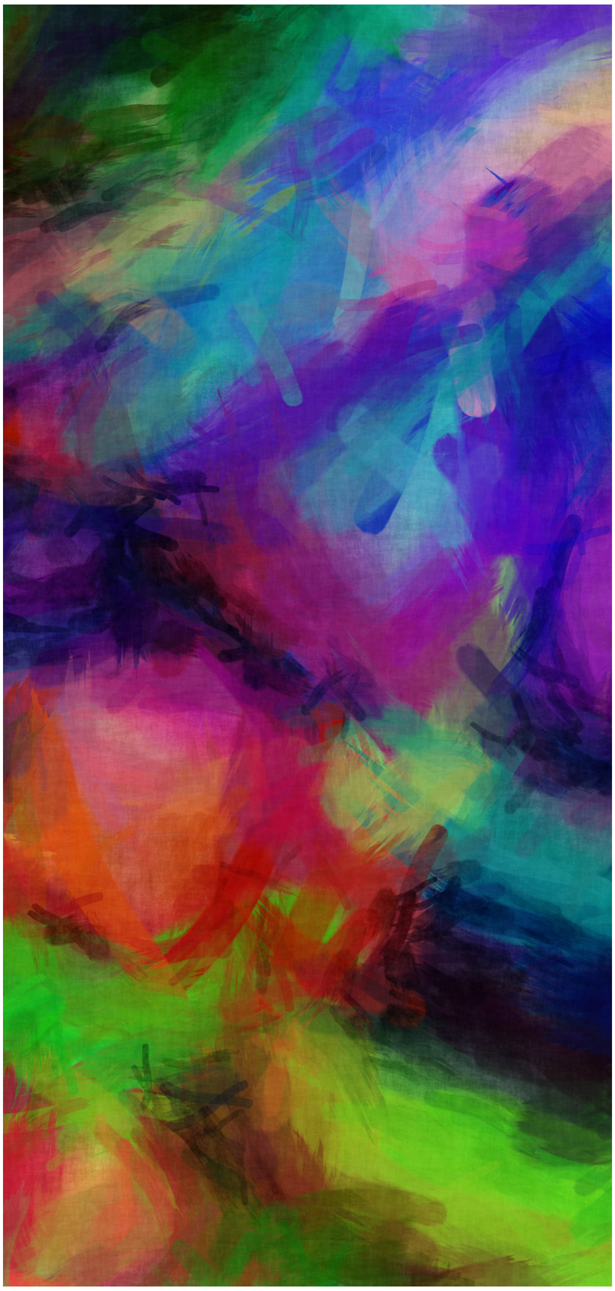
The MMI selected ten projects to commence in 2012:

1. Bioengineered corneal endothelium for improved restoration of sight
2. *Developing nanocomposites for soft tissue regeneration (also funded by Bio21)
3. *Electronic and optical characterisation of nanowire-based device architectures at milli-Kelvin temperatures
4. *Hybrid graphene-single molecule magnet spintronics
5. *Is glycogen an ideal drug-delivery molecule?
6. Museum collections, climatic conditions and monitoring *in situ* physical changes
7. *On-demand degradable hydrogels for soft tissue engineering applications
8. Tailoring high efficiency catalysts for the hydrogen economy
9. Tracking cell lineages in *Drosophila melanogaster* using nanodiamonds
10. *Tracking of intrinsic fluorescent biomarkers in sunscreen.

*MMI-funded projects.

2012 applications

In the 2012-2013 selection round, delegates from the MMI's Management Committee have assessed over 25 applications and selected ten projects to be funded in 2013. The MMI will support seven projects by providing $30 000 to each.



Bioengineered corneal endothelium for improved restoration of sight

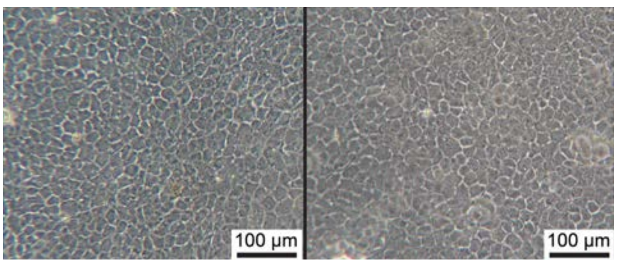
Investigators: Dr Anton Blencowe, Prof Greg Qiao, Dept of Chemical and Biomolecular Engineering; A/Prof Jean-Pierre Scheerlinck, Faculty of Veterinary Science; Dr Mark Daniell, Dept of Ophthalmology.

Purpose

The foremost reason behind corneal transplantation is the loss of corneal endothelial cell function. Corneal endothelial cells (CECs) are specialised, polygonally shaped cells that reside on the inner surface of the cornea to preserve the cornea's transparency. Various factors can lead to the loss of CECs, such as aging, trauma, and disease. Once the CEC numbers are critically reduced, the cornea loses its optical clarity, leading to blindness. Human CECs do not regenerate *in vivo*, thus when CECs lose function, it becomes necessary to undergo corneal transplantation to restore vision.

Various transplantation methods are available, ranging from the replacement of the whole cornea to the replacement of the diseased cell layer only. As a result of the highly invasive nature of full thickness corneal transplants, less invasive methods such as Descemet's Stripping Endothelial Keratoplasty (DSEK) have been developed. With all types of corneal transplantation techniques utilising donor tissue there are risks associated with tissue rejection and graft failure. As such, the development of an autologous transplant for the treatment of corneal endothelial dysfunction is exceedingly attractive.

The aim of this project is to develop biodegradable and biocompatible substrates to support the attachment and proliferation of human CECs for ultimate transplantation into patients to restore vision. The team intends to develop these substrates with appropriate mechanical properties and thicknesses (approx. 50 µm) to make them suitable for minimally invasive procedures such as DSEK.

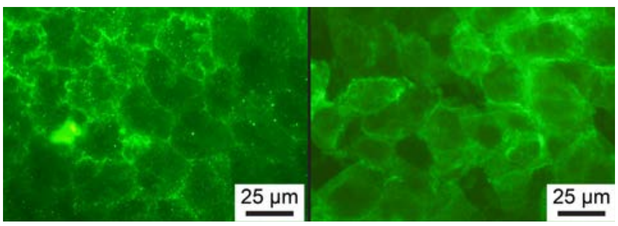


Animal CECs cultured on (left) tissue culture plate and (right) poly(ethylene glycol) (PEG) hydrogel film (PHF). Credit: K. Brown, B. Ozcelik.

Progress

Towards the aim of alleviating corneal endothelial dysfunction, the team has developed ultrathin, biocompatible and biodegradable poly(ethylene glycol) (PEG) hydrogel films (PHFs) via a novel synthetic approach. The PHFs are mechanically robust substrates for the regeneration of corneal endothelial cells (CECs), whilst retaining optical clarity and fluid/nutrient transport. The 50µm thin hydrogel films possess greater tensile strengths and ultimate strains to human corneal tissue. Light transmission measurements at all wavelengths of visible light revealed that the films were more than 98% optically transparent, whilst *in vitro* degradation studies revealed that the films are biodegradable. Cell culture studies demonstrated the ability of the PHFs to support the attachment and regeneration of sheep CECs.

Although animal CECs do not regenerate *in vivo*, it was demonstrated that these cells proliferate on the PEG hydrogel films with natural morphology and 100% confluence within seven days. Implantation of the PHFs *in vivo* into animal corneas demonstrated the robustness of the films for surgical purposes. Regular slit lamp examinations and histology of the cornea 28 days after surgery revealed minimal immune responses and no toxicity, indicating that the PHFs are benign. In conclusion, ultrathin PEG hydrogel films are excellent candidates as platforms for the regeneration and transplantation of corneal endothelial cells with excellent mechanical, optical, biocompatible, and degradation properties.



Na+K+ATPase immunostaining of (left) CECs on native cornea, (right) CECs on PHFs. Presence of green fluorescent staining on the periphery of the cells indicates the function of the cultured CECs on the PHFs. Credit: K. Brown, B. Ozcelik.

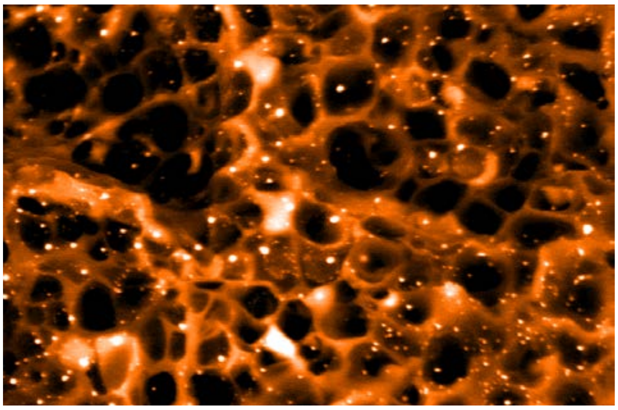
Developing nanocomposites for soft tissue regeneration

Investigators: Dr Phong Tran, A/Prof Andrea O'Connor, Dept of Chemical and Biomolecular Engineering; Dr Dianna Hocking, Dept of Microbiology and Immunology.

Purpose

This project aims to develop composite materials for repairing soft tissue damage resulting from injuries or surgical procedures. The current materials often lack bioactivity for the optimal tissue growth necessary for strong attachment to host tissue. Furthermore, they suffer from bacterial colonisation causing infection.

The team uses an innovative approach to designing the next generation of non-drug based biomaterials for soft tissue regeneration to improve bioactivity and antimicrobial activity of soft tissue implant polymeric materials. Compared to traditional approaches which incorporate antibiotics into polymers, this non-drug design has the major advantage of its potential effectiveness against drug-resistant bacteria which currently present a huge challenge to infection prevention and treatment.



False colour high-resolution image of nanocomposite showing the metal nanopoarticles are well-dispersed inside the polymer matrix. These composites have potential to be used as soft tisssue implant materials to promote tissue formation. Credit: P. Tran, D. Hocking and A. O'Connor.

Progress

The team has successfully developed a novel nano-composite, polymer-based material composed of antimicrobial metal nanoparticles uniformly dispersed in a polymeric matrix that can allow for a controlled release of antimicrobial agents to prevent bacteria growth. Results showed decreased bacterial growth on these composites compared to polymer matrix alone. Titanium dioxide nanoparticles were also introduced to enhance bioactivity of the composites. These composites were shown to improve mammalian cell adhesion, spreading and proliferation. It was also demonstrated that these improvements are likely the results of combinational effects of surface hydrophilicity and element elution. These composites can have potential in repairing soft tissue damages. The team is now in the position to expand the bacteria type to include more implant-related pathogens. They have also identified prospective partner for animal studies of these composite materials. The outcomes from this project are also being used to develop proposals for funding from the Australian Research Council in 2014.

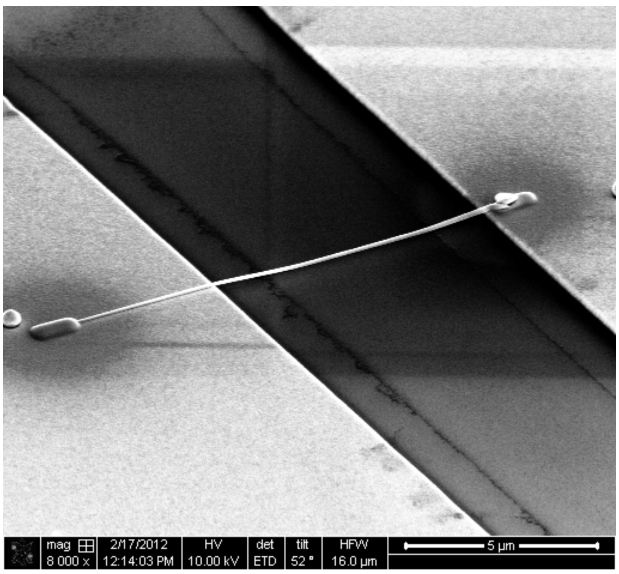
Electronic and optical characterisation of nanowire-based device architectures at milli-Kelvin temperatures

Investigators: Dr Laurens Willems van Beveren, A/Prof Jeff McCallum, School of Physics; Mr Thanh Nguyen, Prof Stan Skafidas, Dept of Electrical and Electronic Engineering; Prof Chennupati Jagadish, Mr Prakash Prasai, Dr Hoe Tan, Dept of Electronic Materials Engineering, Australian National University.

Purpose

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 cryogen-free dilution refrigerator installed in the School of Physics in 2011 allows researchers to further investigate nanowire-based devices spectroscopically, 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. It will also help determine how they can best be tailored to be exploited in a broad range of optical, electronic and sensing applications and lead to new commercial device development and further research.



Progress

The ANU's sub-team has successfully grown indium-phosphide nanowires of about 100nm in diameter, using metal organic chemical vapour deposition. A focussed-ion beam was then used to 'write' electrical contacts made of platinum to these nanowires. These prototype devices were subsequently characterised as a function of temperature in the dilution refrigerator setup of the University of Melbourne. For this purpose a very low-noise, variable-gain current-to-voltage pre-amplifier was purchased. The current-voltage characteristic of these devices at room temperature indicated that the wires were conducting, but only up to a two-terminal measured impedance of a few tens of gigaohms, as the wires were grown intentionally without dopants. Because of this, the electronic charge carriers freeze out at temperatures below approximately 40K.

Photo-excitation of these intrinsic nanowires by illuminating them with (above bandgap frequency) low-temperature compatible light-emitting diodes did not show any conductance change. The next series of nanowire devices will require a higher doping density in order to characterise them at milli-Kelvin temperatures, where they can subjected to large magnetic fields.

Furthermore, in collaboration with the Department of Electrical and Electronic Engineering, the team has looked at the radiofrequency properties of silicon-on-insulator (SOI)-based nanowires for the purpose of building CMOS-compatible nanowire biosensors. Device simulations plus key ideas were published in a CRC Press book chapter. Fabrication and characterisation of SOI nanowires is still ongoing at the Melbourne Centre for Nanofabrocation.

Scanning electron micrograph of a five-micrometre long indium-phosphide nanowire suspended between two gold electrodes. The nanowire is electrically contacted to the electrodes with a platinum beam using a focussed ion beam. The nanowire carries a current from source to drain contact. Credit: P. Prasai.

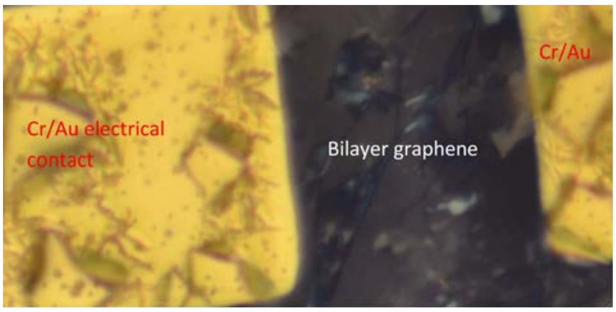
Hybrid graphene-single molecule magnet spintronics

Investigators: Dr Kin Kiong Lee, A/Prof Jeff McCallum, School of Physics; Dr Colette Boskovic, Dr Alessandro Soncini, School of Chemistry.

Purpose

Hybrid graphene single-molecule magnets can be made to act as switches by flipping the spin of electrons. This allows information to be stored as 0s and 1s as in a conventional transistor memory device. An obvious application is a magnetic version of a random access memory device. The advantage of magnetic random access memory (MRAM) is that it is 'non-volatile' – information is not lost when the system is switched off. MRAM devices would be smaller, faster, cheaper, use less power and would be much more robust than the flash memory, and the potential market is worth US$100 billion annually.

Key factors in progressing towards the development of spintronic devices are research into new ferromagnetic semiconductors and a comprehensive understanding of the ferromagnetic mechanism. The research will focus on grafting the erbium polyoxometalate single-molecule magnet (SMM) onto graphene to form a new hybrid electronic device. The chosen polyoxmetalate ligands have an inherent affinity for the graphene surface, to facilitate the construction of the hybrid device. Large area of few-layered graphenes will be grown by ion-implantation of carbon into nickel films and upon annealing at high-temperature, the carbon atoms will diffuse out to the surface of the nickel and be reconstructed into graphene.

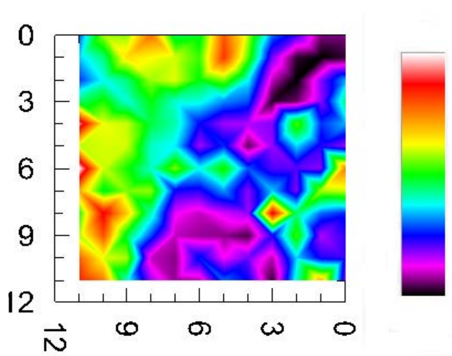


A bilayer graphene back-gated transistor with source and drain electrical contact to facilitate electrical measurement and transport. Credit: K. K. Lee.

Progress

The growth of large area graphene layers via ion-implantation is highly crucial to the success of this project. As the team does not have a vacuum furnace with high-temperature capability, one has to be constructed for this project. Some components of the furnace took six months to arrive from companies and as a result there was a delay in the growth of graphene. Upon completion of the furnace, few-layered graphenes were successfully grown on nickel films, but not without first understanding the stress of the nickel films that have undergone high-temperature treatment. Stress in the nickel films affects the growth orientation <111> of polycrystalline nickel, which serves as a stencil for the graphene layers. Nevertheless some successful large area graphenes were grown by this method, as observed by Raman spectroscopy. Erbium polyoxometalate single-molecule magnets and graphene transistors were successfully fabricated.

The measurement of the magnetoconductivity of the hybrid graphene-SMM has to be performed in a dilution fridge at low-temperature. In addition, the magnitude of the magnetic field has to be tuned quickly from zero to a specific value. However, presently the sample stage mounted in the dilution fridge generates eddy currents under a varying magnetic field strength and heats up the environment of the fridge leading to a temperature fluctuation in the system. The team is currently looking to solve this problem.



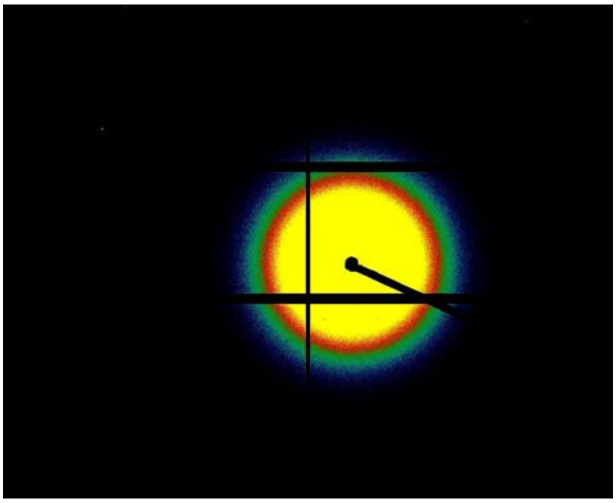
A map (12x12 micrometre) of graphene layers on nickel grains. Colour bar: black denotes one monolayer and red denotes four monolayers of graphene. Credit: K. K. Lee.

Is glycogen an ideal drug-delivery molecule?

Investigators: Dr Angus Gray-Weale, School of Chemistry; Dr Stephen Leslie, Murdoch Children's Research Institute.

Purpose

Glycogen is a highly branched glucose polymer, used to store energy in eukaryotes. The team will develop glycogen particles as cheap, biocompatible polymers of controlled size. Chemotherapy's effectiveness can be drastically improved by attaching the drug molecule to a non-toxic, biocompatible, highly branched polymer. Glycogen is such a polymer, but it has never been used for this purpose. Where glycogen is naturally occurring and readily available, dendrimers and their randomly branched, synthetic cousins are difficult to make, especially where control of larger sizes is needed. Dr Gray-Weale and Dr Leslie tested their ability to control cheaply and easily the sizes of glycogen molecules, and made a systematic study of the stability and response of glycogen particles to solvent, to mechanical stress, to acid, to aging and to temperature, and identified the conditions under which glycogen particles aggregate.



A colour-contrast image of the first small angle X-ray scattering of glycogen. Particle density and shape imformation can be deduced from this image. Credit: Q. Besford, A. Gray-Weale.

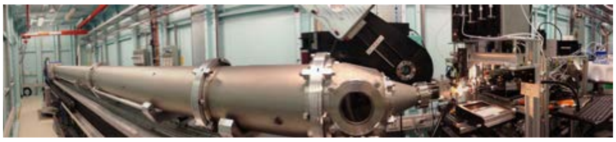
Progress

The team's main result is that glycogen alpha particles are bound together by phosphodiester bonds between their constituent beta particles. This work opens up a new line of research into the enzymes that make and break this bond. Glycogen alpha particles are found to have different sizes in different tissues, and Dr Gray-Weale and Dr Leslie's discovery of the binding mechanism helps connect structure to function. Their finding that cardiac glycogens are alpha particles of size intermediate between that of the liver and muscle particles provides a further piece of this puzzle. The particles' structure optimises availability of glycogen against the thermodynamic cost of storage.

The research team found that over time biological glycogens tend to aggregate, making them unsuitable for any practical use. These aggregates resemble structures seen in some glycogen storage diseases. Commerically available glycogens do not aggregate, and so are useful, because their outer chains have been shortened by the harsh conditions used in their preparation.

Drs Gray-Weale and Leslie used small-angle X-ray scattering (SAXS) at the Australian Synchrotron to measure the distribution of glucose in various glycogens, and so obtained information about the density of chains at the surfaces of the particles.

Using both SAXS and Dynamic Light Scattering, they compared the glycogen particles taken from healthy and diabetic mice, provided by Prof Jiming Ye (RMIT). These results and their implications for the mechanism of type II diabetes will be published shortly.



A panorama of the small angle X-ray scattering beamline at the Australian Synchrotron. Image shows glycogen samples being loaded into the capillary, where the X-ray will shoot through and the scattering detected at the end of a seven metre vacuum. Credit: Q. Besford, A. Gray-Weale.

Museum collections, climatic conditions and monitoring *in situ* physical changes

Investigators: Dr Nicole Tse, School of Historical and Philosophical Studies; A/Prof Ann Roberts, School of Physics.

Purpose

Recent concerns about climate change and the recognition of museums in diverse environmental locations, are driving heritage professions to reconsider the international museum standards of 20°C ±2 °C and relative humidity of 50% ± 5%. Although recent research suggests that the tolerable limits for museum objects are larger than previously thought possible, 'damage functions' specific to unique works of art still need to be developed. In practice, conservators currently rely on temperature and relative humidity monitoring as the diagnostic tool for their decisions. However environmental monitoring in itself does not measure the response of unique museum objects that have diverse ageing properties, historical usages, formulations, composite structures and rates of reaction.

To better understand an object's range of mechanical responses to its surrounding environment, a laser speckle sensor has been developed to measure 'temporal activity' or spatial data from the surface of historical artifacts as the environment changes *in situ*. Spatial data from the laser speckle unit has been integrated with temperature, relative humidity, pressure, non-contact temperature and moisture sensors to quantitatively obtain dimensional information and develop 'damage functions' for unique cultural artifacts. The speckle sensor has also being applied to measure water transport in leaves.

In situ DSA sensor assessing a work of art by Mary Norrie, circa 1970, oil on canvas, donated by the Estate of Mary Norrie, Collection of CCMC.

Progress

Using dynamic speckle analysis (DSA) has allowed the team to monitor the 'temporal activity' from acrylic paints, bark painting support, paper-based items and canvas paintings aged in varying environments and the effects of air conditioning and environmental changes on these items. This has been achieved with the development of a mobile DSA unit integrated with pressure, temperature, light and relative humidity readings with a user-friendly computer interface built by the Department of Electrical and Electronical Engineering. Identifying the most suitable laser speckle experimental set up for *in situ* use along with the necessary algorithms for analysis, automation and diagnostic limitations has been an important part of the process. As the laser speckle sensor is used at low intensities, it is non-invasive and non-destructive, making it ideal to investigate cultural materials.

The successful use of the DSA has supported the research of two Centre for Cultural Materials Conservation's (CCMC) Minor Thesis projects and data for three publications under way. The DSA sensor has been used *in situ* at RMIT and Silpakorn University (Thailand) and further usage is planned for 2013 with institutional industry partners. Being able to demonstrate the DSA's capabilities through industry partner collaborations and publications will garner interest for a proposed ARC Linkage grant.

Overall the productive collaboration between the CCMC, School of Physics and Dept of Electrical and Electronical Engineering has highlighted the potential of DSA to monitor works of art. In 2013, thanks to an MMI supported grant, Dr Nicole Tse, A/Prof Ann Roberts, A/Prof Peter Farell, Dr Graham Brodie, Prof Carl Schiesser and Caroline Kyi aim to study the use of radio frequencies to monitor changes in significant cultural materials.

Acknowledgements: Jessica Kvansakul, School of Physics; A/Prof Peter Farell, Peter Zhong and Dr Xuezhi Wang, Dept of Electrical and Electronical Engineering; A/Prof Supanee Chayabutra, MCad, Silpkaorn University, Thailand; Mr John Buckingham, Curator, RMIT Gallery; ARC Linkage grant 'The Twentieth Century in Paint'.

On-demand degradable hydrogels for soft tissue engineering applications

Investigators: Dr Katharina Ladewig, Dr Anton Blencowe, Prof Greg Qiao, Prof Geoff Stevens, Dept of Chemical and Biomolecular Engineering; Prof Wayne Morrison, Faculty of Medicine, Dentistry and Health Sciences (FMDHS), O'Brien Institute; Dr Keren Abberton, Mr Jason Palmer, (FMDHS).

Purpose

Tissue engineering (TE) emerged in the early 1990s to address limitations of organ transplantation and synthetic tissue replacements, focusing on coupling cells and a biocompatible matrix known as a scaffold. Since then, some clinical success was achieved with hard tissue replacements and for two-dimensional soft tissues, while the repair or augmentation of soft tissue defects has so far eluded successful translation into the clinic. Adipose tissue engineering has emerged as an alternative to current treatments. It is a very soft tissue hence very soft TE scaffolds such as hydrogels are required for its engineering.

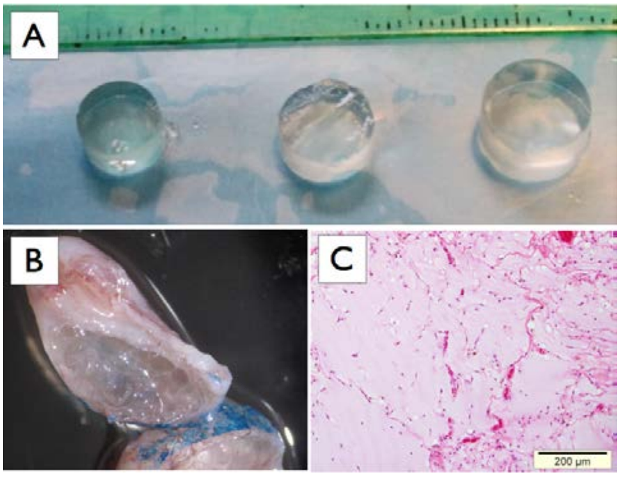
Previous work by the team of investigators showed that an active degradation mechanism for these hydrogel scaffolds is required to better align the timescales of *de novo* tissue formation and scaffold degradation whilst increasing cell attachment to the synthetics hydrogels. As part of normal tissue function many cells secrete a class of enzymes known as metallo-matrix proteases (MMPs), which are capable of degrading virtually any extra-cellular matrix (ECM) protein that possesses a recognisable cleavage-sequence. Incorporation of small molecules mimicking those cleavage sites should therefore enable on-demand cleavage of the scaffold as cells migrate into the scaffold. This approach should also allow the team to align the timescales of degradation and *de novo* tissue formation.

This can be combined with improved cell attachment by the simultaneous inclusion of RGD sequences (short peptide sequences mimicking the cell binding domain of ECM molecules) into the network structure and the potential to deliver small, hydrophobic, bioactive molecules by incorporating hydrophobic nanodomains into the hydrogels. Due to their hydrophobic nature these bioactive molecules will preferentially bind to the hydrophobic core of core cross-linked (CCS) polymers as championed by Prof Greg Qiao's group. They will not diffuse out of the otherwise hydrophilic hydrogel matrix, but will only be released once the cells start to actively degrade the hydrogel by cleaving the MMP recognition peptides.

Progress

The synthesis procedure for fully-biodegradable, hydrophobic CCS polymers has been established and trials for their incorporation into PEG hydrogels were completed. It was further shown that hydrophobic drugs can be incorporated into the hydrophilic hydrogels via hydrophobic interaction with the CCS polymers which are covalently bound to the hydrogels using NHS/EDC mediated or Michael-addition type reactions.

The novel approach to tune the degradation of the hydrogels based on cellular demand via MMP-mediated degradation was developed in collaboration with an overseas laboratory, which the chief investigator visited in early 2012. It was shown that this approach can also be used to modulate drug release from the hydrogels. Preliminary animal trials that evaluate the suitability of these hydrogels for *in vivo* applications are currently under way both in Australia and overseas.



(A) Hydrogels of varying composition prior to *in vivo* implantation. (B) Macroscopic image of explanted hydrogel after 8 weeks *in vivo* incubation. (C) Histological image (H&E staining) of explanted hydrogel showing cellular infiltration and *de novo* vascularisation. Credit: K. Ladewig.

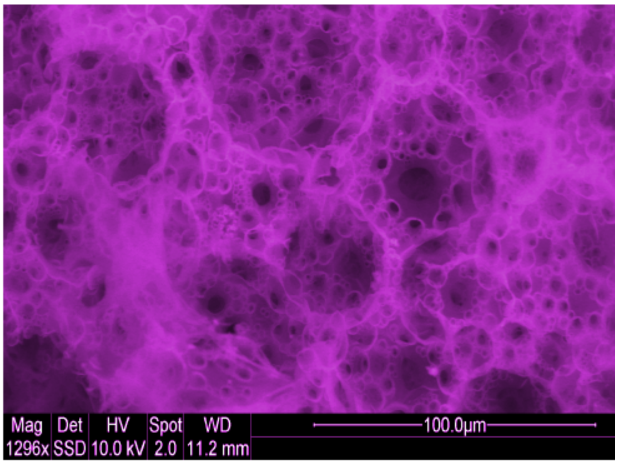
Tailoring high efficiency catalysts for the hydrogen economy

Investigators: A/Prof Andrea O'Connor, Dept of Chemical and Biomolecular Engineering; A/Prof Michelle Gee, School of Chemistry; Prof Ulrich Wiesner, Dept of Materials Science, Cornell University.

Purpose

Changes in global energy demands and the prospect of shifting towards a hydrogen economy in the future are driving increasing demand for new kinds of engineered nanostructured materials. Two significant challenges to achieve this outcome are the development of superior catalysts and supports to enable conversion of solar energy to chemical energy and the production of hydrogen from carbon-containing fuels, biomass and water with greater efficiencies than are currently available.

Hierarchically porous materials have potential to fulfill this requirement by providing functional materials with high accessible surface areas, size selectivity and designed chemical properties. However, to date our ability to produce such materials with porous architectures controlled over several key length scales has been limited. Existing methods to create hierarchically porous materials tend to result in materials with unsatisfactory properties. These methods are also unsuitable to scale up for industrial use. This project aims to overcome the limitations of current materials to produce novel porous materials which can be tailored as more efficient catalysts.



Progress

Significant progress has been made on the production of hierarchically porous inorganic materials during 2012.

Firstly, materials have been produced using soft templates created by surfactant molecules in solution (micelles) and emulsion droplets, resulting in well-controlled internal porosity comprising meso and macro-pores (termed 'co-MET materials'). The two populations of pores can be controlled independently to provide beads with large macropores for rapid throughput and a narrow size distribution of mesopores, creating high surface area and size selectivity for molecular access. The control and understanding of the production of these materials has developed so they can be made reproducibly and their chemical and physical properties manipulated to suit target applications as catalysts and adsorbents. Work has begun on producing a variety of chemical compositions of such materials incorporating active catalytic sites for hydrogen production via the water gas shift reaction.

Secondly, the strength of the silica beads has been improved through control of the polymerisation reactions used in their synthesis. A third key development in this project in 2012 was to create entirely new nanoporous architectures using block copolymers custom-made by our collaborator, Prof Ulrich Wiesner at Cornell University. This process provides the ability to design and optimise the internal architecture of the materials by controlling the macromolecular architecture used to produce the materials. The new architectures are expected to open up the potential applications of these materials by allowing their design across a range of length scales to suit the target molecules and process throughputs.

False-colour scanning electron microscopy image showing the macropores inside a bead of co-MET silica, templated from droplets of oil in an emulsion. Credit: A. Tan, M. L. Gee, A. J. O'Connor.

Tracking cell lineages in *Drosophila melanogaster* using nanodiamonds

Investigators: Dr David Simpson, School of Physics; Dr Michael Murray, Dept of Genetics; Dr Yan Yan, Dept of Chemical and Biomolecular Engineering.

Purpose

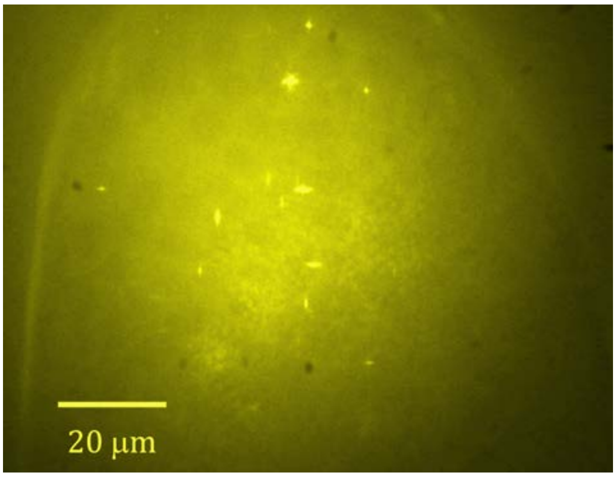
The development of multicellular animals can be thought of as a complex tree of cell divisions, beginning with the original single celled zygote, and culminating in the myriad differentiated cells of the final organism. Our understanding of developmental mechanisms can therefore be enhanced by methods for analysing cell lineages.

This interdisciplinary project targets the common fruit fly, *Drosophila melanogaster*, a developmental model organism of outstanding importance in medical research to trial a fundamentally new methodology for studying cell lineages. The approach takes advantage of the extraordinary property of nanodiamonds that allows individual nanoparticles to be identified, tracked and correlated over long periods of time. The potential for tracking complex cell lineages will greatly enhance our understanding of the development of *Drosophila* embryos. Given that 75% of known human disease genes have *Drosophila* orthologues (homologous gene sequences) the team anticipates that these novel techniques will have far reaching impact on the diagnosis and treatment of diseases.

Progress

The interdisciplinary team from Physics, Genetics and Chemical and Biomolecular Engineering has established techniques for the micro-injection of nanodiamonds into *Drosophila melanogaster* during the early stages of embryonic development. Using two distinct optical imaging techniques, the molecular dynamics of the individual fluorescent nanodiamonds injected into the embryos were studied.

Analysis showed local viscosity differences between nanoparticles injected into the embryo's yolk compared with those located in the blastoderm cells during the stage five (cellularisation) of the embryonic development. This is the first successful delivery and characterisation of nanodiamonds in this model embryo system. The results of the study were recently presented at the National Australian Institute of Physics Congress in December 2012. These initial results set the scene for future cell linage tracking studies.



False-colour wide-field fluorescence image of nanodiamonds in the *Drosophila melanogaster* embryo. Credit: D. Simpson, J.Thompson.

Tracking of intrinsic fluorescent biomarkers in sunscreen

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

Purpose

This project aims to develop and optimise a novel non-invasive optical method for tracking nanoparticles in zinc oxide (ZnO) based sunscreens that are absorbed through human skin.

In Australia, more than 10 000 people were diagnosed with melanoma in 2007. Sunscreens are widely promoted as preventative barriers to UV exposure and the active components are usually ZnO and titanium dioxide (TiO_2) which can be in nanoparticle form. Reducing the size of the particles to nanoparticles results in a transparent sunscreen that is easily absorbed by the skin.

Despite the widespread use of sunscreen, there have been serious questions raised regarding their safety, even including a possibility of increased risk of melanoma due to sunscreen use. There is therefore a pressing need to monitor the propagation and accumulation of nanoparticles through biological tissue with the most sensitive techniques available.

The team has discovered that ZnO nanoparticles themselves can act as bright, single photon sources, and can therefore be used as fluorescent biomarkers in their own right. This discovery enables the possibility of using highly sensitive scanning confocal fluorescence techniques to track nanoparticle propagation through biological tissue at the single nanoparticle level. In addition to the discovery of single photon emission in ZnO nanoparticle films, the team has also observed intrinsic fluorescence in commercially obtained sunscreen.

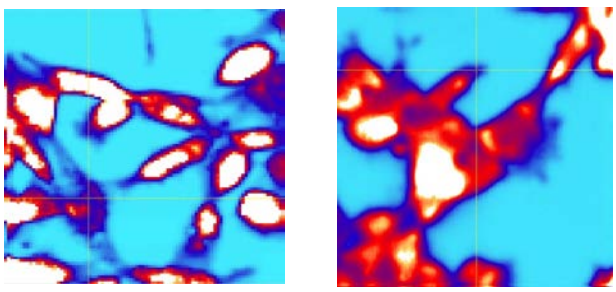
The primary challenge of this project will involve engineering the properties of the fluorescent emitters in ZnO, and possibly in TiO_2, to obtain stable room temperature emission. As a first step towards this goal, this project aims to determine the factors that limit their photostability and whether a viable biomarking platform can be made around ZnO nanoparticles.

Progress

This project started as a collaborative effort between Physics and Bio21 and eventually included Dr Phong Tran from the Tissue Engineering Group (Dept of Chemical and Biological Engineering). PhD student Asma Khalid (School of Physics) was also involved in all aspects of this project.

Zinc oxide nanoparticles (NPs) and NP-derived thin films were synthesised in Bio21. The NPs were added to skin cell culture produced in the Tissue Engineering lab and optically characterised at the School of Physics. Scanning fluorescence confocal maps of the annealed films as well as sunscreen samples demonstrated a high spatial density of bright optical defect centres that exhibit blinking in their emission over time. Individual NPs dispersed in solvents showed decaying counts *versus* time behaviour, which was of the order of seconds. Skin cells with incorporated ZnO have been cultured and optically analysed with visible light and no added fluorescent tags.

In future work the team will continue to monitor and study the propagation and accumulation of nanoparticles in sunscreens through biological tissues with non-invasive optical techniques in the visible and no added fluorescent tags. The team's main target is to increase stability and longevity of ZnO NPs.



Confocal images: ZnO in skin cells. Credit: A. Khalid, P. Tran.

Platform Development Pilot Program

Started in March 2012, the Platform Development Pilot Program (PDPP) is establishing a framework to facilitate access and provide support to platform technologies widely used by the University's materials research community.

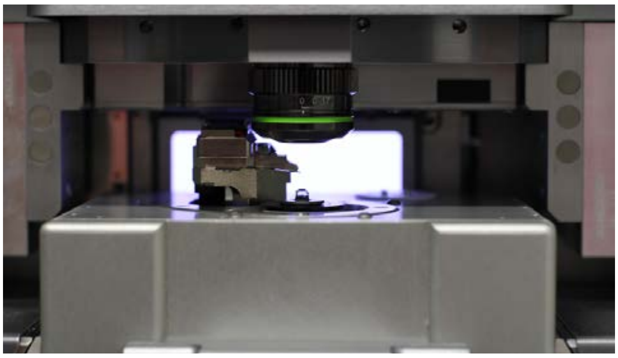
The pilot program is an initiative instigated and overseen by the MMI, in partnership with the Melbourne School of Engineering and the University's Research Infrastructure Strategy Office.

Following an open advertisement for research academics to propose and lead platforms which would benefit from the provision of a dedicated support technician, two platforms were commissioned:

- Nanomaterials Characterisation (NC) led by A/Prof Raymond Dagastine, and
- Advanced Fluorescence Imaging (AFI) led by Dr Angus Johnston.

As part of the program, the MMI has appointed Platform Support Officers Ms Marta Redrado Notivoli (NC) and Mr Benjamin Hibbs (AFI). The platform support officers provide assistance to use for the platform under the direction of their respective academic leaders, whose responsibility include promoting the platform and reporting on usage.

The MMI Technical Support Manager is developing a platform to support nanofabrication activities. A Platform Support Officer will be seconded to the Melbourne Centre for Nanofabrication in the near future to support University researchers.



The Cypher AFM, the world's highest resolution AFM. Credit: Marta Redrado.

Nanomaterials Characterisation

Leader: A/Prof Raymond Dagastine
Support Officer: Marta Redrado Notivoli

Capabilities

This platform is a combination of atomic force microscopy (AFM), colloidal characterisation equipment and nano-indentation capabilities and supports research activities in engineering, science and medicine. The Nanomaterials Characterisation platform can provide information on surface topography, nano-mechanical properties, elasticity, surface forces and electrical properties.

The AFM suite has provided users nano-scale visualisation of materials relevant to semiconductor processing, of thin films, of advanced materials coatings, of organic solar cells and organic light-emitting diodes as well as living cells including bacteria, and mammalian cells in liquids.

Support

Through the program, the platform support officer provides access to equipment and technical support on either a service or a user-operated basis. Ongoing support and tailored training programs, based on to previous experience with the equipment, are offered to University and external users.

Users

Since the start of the PDPP, the Nanomaterials Characterisation platform has supported 24 researchers from nine different groups within the Department of Chemical and Biomolecular Engineering, the School of Chemistry, the School of Physics, the WEHI, the Bio21 Institute, and Monash University.

Publications enabled

Since the launch of the platform in August, four articles based on data collected on Nanomaterials Characterisation platform equipment have been published.

Advanced Fluorescence Imaging

Leader: Dr Angus Johnston
Support Officer: Benjamin Hibbs

Capabilities

The only one of its kind in Australia, the Advanced Fluorescence Imaging (AFI) platform provides access to three complementary techniques: super-resolution microscopy, live cell imaging and imaging flow cytometry. These techniques benefit researchers in the fields of nanomedicine, immunology, materials engineering, cell biology and oncology and span the Faculty of Medicine, Dentistry and Health Sciences, the Faculty of Science, and the Melbourne School of Engineering.

Super-resolution microscopy

Until recently, the highest resolution that could be achieved using optical microscopy was limited to about 250nm. However, many nanoengineered materials and structures within cells, such as nanocapsules and cellular membranes are smaller than this limit. The super-resolution microscopes at the AFI platform offer the ability to break this resolution limit and resolve structures as small as 20nm.

Live cell imaging

In addition, the AFI platform enables users to understand interactions in living cells by offering super-resolution live-cell imaging down to 100nm, as well as conventional live-cell imaging.

Flow cytometry imaging

Imaging flow cytometry enables structural information to be gathered at a rate in excess of 100 cells per second, allowing meaningful statistical information to be obtained.

Support

Access is available to researchers from the University of Melbourne, as well as the wider community. The AFI platform equipment requires significant skill and expertise to operate. To facilitate access, a full-time platform support officer is available to run samples and train repeat users. Due to the specialised nature of operation, the super-resolution microscopes (Nikon N-STORM and OMX BLAZE) are only available for assisted use with the platform support officer.

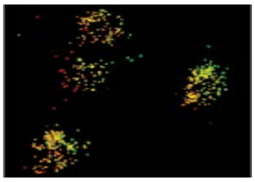
Users

Since its launch in September 2012, the platform has been used by researchers from the Faculty of Medicine, Dentistry and Health Sciences, the Faculty of Science, and the Melbourne School of Engineering. It has also attracted users institutes such as the Florey Institute of Neuroscience and Mental Health, the Walter and Eliza Hall Institute and the Monash Institute of Pharmaceutical Sciences.

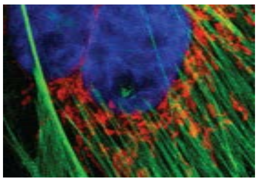
Publications enabled

Six publications involving collaborations between five research groups have been published using data collected on instruments covered by the Advanced Fluorescence Imaging platform.

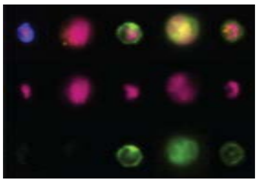
Samples of images generated with the AFI platform's equipment; from the top down:



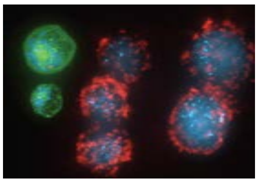
STORM: Single colour STORM image of clathrin-coated pits in a mammalian cell labelled with Cy3-Alexa647.Credit: Zhuang group, Harvard University.



SIM: Three-colour structured illumination image of bovine pulmonary artery endothelial cells stained with MitoTracker Red for labelling mitochondria (red), Alexa Fluor 488 Phalloidin for labelling F-actin (green) and DAPI for labelling the nucleus (blue). Credit: Applied Precision, University of Melbourne.



Deconvolution: Fluorescence microscopy images of LIM2405+ cells (blue) and LIM2405- cells (green) incubated with huA33 mAb- functionalised capsules (red). Credit: A. Johnston, University of Melbourne. Published in *Journal of the American Chemical Society*, 2005,127, 28, 10014–10015.



Imaging Flow Cytometry: CD14+ monocytes (green) and CD56+ NK T cells (blue) stained with Draq5+ to label the nucleus (red). Credit: A. Johnston, University of Melbourne. Published in *Journal of Immunological Methods*, 2012, 384, 51–61.

MCN Access Scheme

The Melbourne Centre for Nanofabrication (MCN), Clayton,Victoria. Credit: MCN.

Launched in June 2012, the Melbourne Centre for Nanofabrication (MCN) Access Scheme enables researchers from the University of Melbourne to access the MCN facilities at discount rates.

What the MCN offers

The purpose-built, state-of-the-art MCN:

- Provides expertise in the areas of advanced materials, biotechnology and characterisation techniques
- Comprises a unique array of fabrication and characterisation equipment
- Is an ideal hub for collaboration projects between academic and industry users.

The MCN primarily supports activities by training researchers to become proficient users of the equipment available at the facility. The MCN also operates a fee-for-service model.

Access options

While the MCN's facilities are accessible to academia and industry (see MCN website for details), the MMI offers two cost-saving options to University of Melbourne researchers.

Pre-paid time

The MMI offers the use of its pre-paid account for researchers from the University of Melbourne (UoM). The account provides for a 30% discount on usage charges, which the MMI passes on to the user.

Merit-based application

In addition to paid access, the UoM-MCN User Group Committee invite applications from UoM researchers to utilise the MCN for a defined period of free access. The free access supports initial prototyping and/or development activities. These merit-based applications are assessed by the UoM-MCN User Group Committee on a monthly basis. Applications are accepted at any time of the year.

The current UoM-MCN User Group Committee members are:

- Ray Dagastine (Chair) - Chemical and Biomolecular Engineering
- Stan Skafidas - Electrical and Electronic Engineering
- Jeff McCallum - Physics
- Ann Roberts - Physics
- Laurens Willems van Beveren - Physics
- Sach Jayasinghe - Research Infrastructure Strategy Office
- Irving Liaw - MMI.

For more information, visit the MMI website or contact the MMI Technical Support Manager.

PDPP and MCN Access Scheme: an insider's view

A/Prof Ray Dagastine, Academic Leader for the Nanomaterials Characterisation platform, MCN Tech Fellow and the Chair of the UoM-MCN User Group Committee.

You are the Academic Leader for the Nanomaterials Characterisation platform of the PDPP, launched in March 2012. What are your responsibilities in this role?

I have been working with atomic force microscopy (AFM), nano-indentation and materials characterisation since 1996 in areas including polymers and composite materials, and more recently in colloid and surface science with a focus on soft materials. The Nanomaterials Characterisation platform provides nano-scale surface and materials characterisation through a combination of AFM, colloidal characterisation and nano-indentation capabilities. I work with the platform technical officer, Marta Redrado, to provide to support a broad range of researchers in engineering, science and medicine. This platform supports activities on either a service or a user-operated basis, tailoring different training programs for users depending on their previous experience.

How effective has the program been in consolidating infrastructure and facilitating access to the University research equipment since it started?

This platform has made great strides in engaging with users across the University providing information on surface topography, nano-mechanical properties, elasticity, surface forces and electrical properties. Since the start of the platform program we have supported a user base of 24 researchers from nine different groups. We are also starting to help support researchers with similar equipment outside the platform to develop a University-wide network in this area.

How do you see the future of the PDPP?

My first hope is that we can remove the word 'pilot' from the program. I feel we've already achieved a critical mass of researchers and are able to support them in a much more effective manner than without the program. The PDPP program has allowed us to move from maintaining a smaller facility with an existing user base to significantly growing the platform capabilities and the number of researchers. I think that the PDPP program can help define a model to establish other platforms within the University.

You are also a Melbourne Centre for Nanofabrication (MCN) Tech Fellow and the Chair of the UoM-MCN User Group Committee. What does your role as MCN Tech Fellow entail?

Technology Fellows support the development of the MCN by contributing to the expertise and collaborative environment at the facility. This includes being at the MCN a minimum of two days a week and as well as having a presence from your research group at the MCN. For me, the Technology Fellowship has been a fantastic opportunity to use nanofabrication in my research on soft materials through the fabrication of custom AFM cantilevers and micro-fluidic devices for manipulating and studying emulsion and foams.

Could you give us an example of what University of Melbourne researchers can achieve by accessing MCN facilities?

A good example is the project of Dr Thanh Nguyen and Prof Stan Skafidas from the Department of Electrical and Electronic Engineering on the fabrication of a biological nanosensor in collaboration with Dr Matteo Altissimo, a senior instrument manager from the MCN. The nanosensors, nanowires overlaid on gold contact fabricated on a silicon wafer by means of electron beam lithography, are sensitive to the binding of a specific type of biological antigen that can be detected using electrical measurements.

What is the main goal of the merit-based option of the MCN Access Scheme?

The goal is to get researchers to engage with the MCN, especially for new or untested ideas. I would encourage any researcher that has considered the MCN as an option to help with some aspect of their research to apply, especially researchers without a fabrication background.

What are your hopes for the scheme in 2013?

My hope is that so many researchers engage with the MCN that we can simplify the scheme so that any researcher new to the MCN can access 15 to 20 hours of free time to get their work started.

Bionic Vision Australia

The bionic eye project

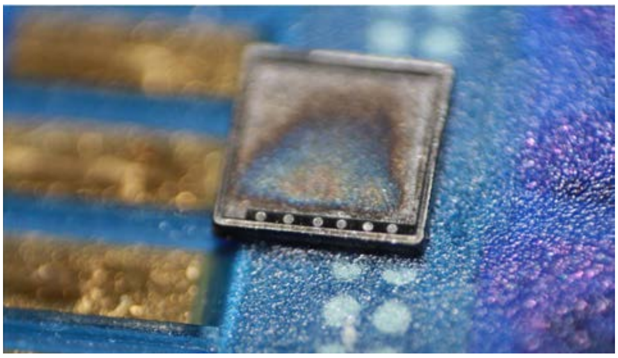
The MMI is a member of the Bionic Vision Australia (BVA) consortium and one of the key developers of BVA's high-acuity bionic eye.BVA is developing a bionic eye to restore a sense of vision to people with degenerative forms of vision impairment, such as *retinitis pigmentosa* or age-related macular degeneration. MMI's involvement in the project is to solve the materials-related problems for the design and encapsulation of high-density a stimulation device and for its connection of to the retina.

Formally launched in March 2010, BVA brings together researchers from the Bionics Institute, the Centre for Eye Research Australia, National ICT Australia (NICTA), the University of Melbourne and the University of New South Wales. The University of Western Sydney, the National Vision Research Institute and the Royal Victorian Eye and Ear Hospital are project partners.

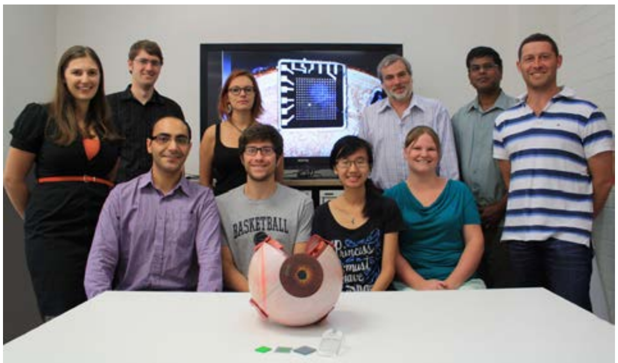
Two retinal implant prototypes are currently being developed: a wide-view device aiming to enable patients to manoeuvre around large objects and a high-acuity device, which will offer greater resolution and allow patients to recognise faces and read large print.

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.



Diamond box that will house BVA's high-acuity device. The device is shown on the pads of an SD flash memory card to give a sense of scale. Credit: D. Garrett.



Members of the BVA diamond electrode fabrication team team behind a 3D eye model with scaled parts of the device responsible for electrical stimulation of the retina: chip, electrode array, diamond box and silicon surround. From left to right, standing: Samantha Lichter, Dr Alastair Stacey, Mathilde Escudié, Prof Steven Prawer, Dr Kumar Ganesan, Dr David Garrett; sitting: Dr Arman Ahnood, Nick Apollo, Wei Tong, Dr Kate Fox.

A growing team

Dr Arman Ahnood joined the MMI bionic eye team in late June 2012 as a material fabrication scientist. His contributions to the project include the development of scalable processes for the integration of the final device and the testing of the device's hermiticity and lifetime, and of the electrical properties of electrodes and interconnects on diamond.

PhD candidate Nick Apollo started with the Centre for Eye Research Australia in September 2011 as a member of the BVA pre-clinical team. He became member of the BVA materials fabrication team in July 2012 and is studying the biological stability of BVA device-related metals.

PhD candidate Wei Tong joined the team in November 2012. She is working on growing neural cells on diamond.

Mathilde Escudié was employed as an intern in December 2012. She is responsible for the quality management of the electrode development process.

Progress update

2012 was a very eventful year for BVA with the successful first implantation of a prototype bionic eye in three patients with *retinitis pigmentosa*. In a public announcement in August, the first patient, Dianne Ashworth, reported seeing flashes of light when her device was switched on.

This milestone in the history of BVA not only demonstrates that the design of the wide-view device is effective, it also validates the technology common to both wide-view and high-acuity devices. In addition, results from this testing will help plan the development of both prototypes.

The research team at the MMI School of Physics is responsible for the design, fabrication and encapsulation of a diamond electrode array for the high-acuity device. In 2012, significant progress was made with this project.

A new type of electrode array has been created by growing Ultra-Nano-Crystalline Diamond within pure diamond to create biostable diamond wires. The resulting monolithic electrode array is fabricated entirely from diamond. This fabrication technique enables the production of arrays comprising large numbers of electrodes.

In addition, the team has successfully demonstrated that the electrodes are electrically isolated and can be stimulated individually. The researchers have also improved the shape of the electrodes, allowing them to sit closer to the retina. Furthermore, pre-clinical testing has shown that diamond is suitable to electrically stimulate ganglion cells in the retina and may even help in promoting nerve growth and healthy neural function.

Moreover, a novel laser brazing technique for the hermetic encapsulation of the array and other electronic parts within the full diamond box has been developed and is currently being tested, as well as a technique to bond the chip to the array. Finally, the team has collaborated with the Bionics Institute on technologies for attaching leads, preparing the soft moulding around the diamond, and for affixing the implant to the retina.

With the aim to accelerate development towards patient testing, the team is currently working on a 256 electrode high-acuity prototype and intends to scale up its design to 1024 electrodes and more in the future. Goals for 2013 include the pre-clinical testing of the device in preparation for patient tests in 2014 (pending further funding).

BIONICVISION
AUSTRALIA

Other teams involved in the development of the high-acuity device have also made much progress, with the fabrication of a second-generation microchip and the design of safe surgical tacking techniques for the placement of the device behind the retina. Engineers at the University of Melbourne have been working on current steering techniques to improve the resolution of the perceived image while the NICTA team has been refining algorithms for simulated prosthetic vision with a view to enable face recognition and depth perception.

Further to the excitement of the successful implantation of an early prototype and the dramatic progress made in the development of both the wide-view and high-acuity devices, BVA is now looking to secure funding after 2013. The $42M ARC grant allocated at the start of the bionic eye project in 2009 will run out by the end of 2013. In order to capitalise on the ground-breaking work achieved so far and fulfill a life-changing dream for millions of people with profound vision loss, the consortium is seeking significant ongoing funding. A public appeal was launched in December to raise further funds.

For more information on this fundraising campaign, go to http://www.helpbuildthebioniceye.org.au.

CSIRO

MMI-CSIRO Materials Science PhD Scholarship program

The program

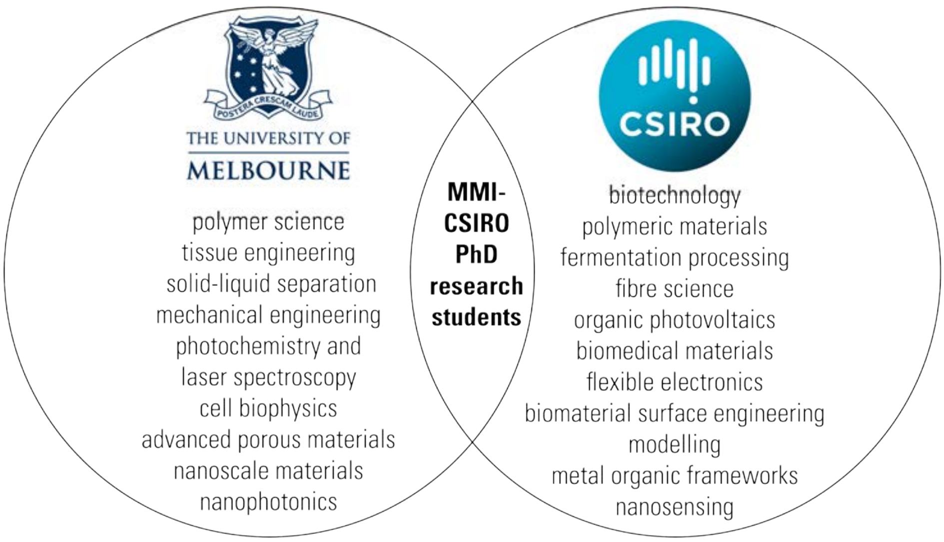
The MMI-CSIRO Materials Science PhD scholarship program is now in its third year and and the cohort of University students with supervisors from both the University and CSIRO has grown to 12. With supervisors from the Melbourne School of Engineering, the Faculty of Science, the Faculty of Medicine, Dentistry and Health Sciences, and CSIRO's Materials Science and Engineering, and Process Science and Engineering Divisions, the students are exposed to a broad range of facilities and opportunities.

PhD projects on offer

The program continues and the following projects are currently on offer:

- Homogeneous catalysts for nitrogen fixation
  CSIRO supervisor: Danielle Kennedy (Analysis and Characterisation)
  University of Melbourne supervisor: Stephen Best (Chemistry).
- Novel temperature responsive polymer as flocculant and collector
  CSIRO supervisor: Liza Forbes (Mineral processing and agglomeration)
  University of Melbourne supervisor: George Franks (Chemical and Biomolecular Engineering)
- Characterisation of cold spray structures produced using a supersonic jet nozzle.
  CSIRO supervisor: Stefan Gulizia (Surfaces and Nanosciences)
  University of Melbourne supervisor: Kenong Xia (Mechanical Engineering).

For more information about current opportunities, please visit the MMI website or contact us.



Scholarship recipient designs groundbreaking virus detection test

Dr Paolo Falcaro (right) and PhD scholarship recipient Fabio Lisi examine vials of quantum dots in the lab. Credit: CSIRO.

As part of a team led by Dr Paolo Falcaro at CSIRO's Materials Science and Engineering Division, MMI-CSIRO PhD scholarship recipient Fabio Lisi is involved in the design of a point-of-care method to detect the Hendra virus. Discovered in 1994 following an outbreak in a large racing stable in the Brisbane suburb of Hendra, the virus threatened to stop Australia's premier horse race – the Melbourne Cup.

Based on quantum dots and magnetic nano-particles, the test detects the presence of the Hendra virus in saliva. "Ideally, [after] collecting the saliva of an infected animal we can just inject the saliva into the device. If we have a bright spot this means the test is positive and you detect the Hendra virus", explains Dr Falcaro. The test currently takes 30 minutes and Dr Falcaro hopes to reduce it to ten minutes.

Besides its speed and portability, one of the test's most promising aspects is its versatility. "The most exciting aspect of this technology is that it could be used to detect any other virus by simply targeting the virus with the corresponding antibody" explains Dr Falcaro.

A member of the research team, Prof Paul Mulvaney, from the Bio21 Institute at the University of Melbourne, says this project is "an important example of how the University of Melbourne-CSIRO partnership can help us focus basic science onto important health challenges".

Dr Falcaro is confident that the first step of this study will lead to a functional device in the near future: "We think that we can fabricate a prototype device for commercial evaluation within three years", he concludes.

The study was published in the *Journal of Advanced Healthcare Materials* and was featured on the front cover of the journal.

Interview with scholarship recipient Fabio Lisi

What was your involvement the Hendra virus detection project? How does it relate to your PhD?

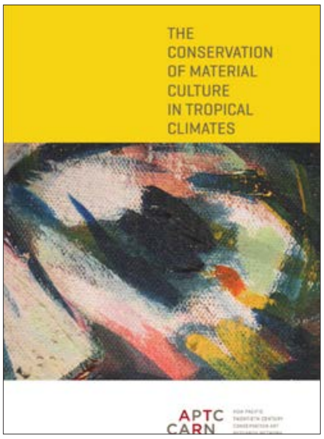
The detection of Hendra virus is a very challenging project that I am glad to be part of. The project faces modern challenges, such as the point of care detection of pathogens, and the possible outcomes could be important from both academic and commercial points of view. The Hendra virus detection project is currently the backbone of my PhD. The multidisciplinarity of the projects has brought me in contact with scientists with different backgrounds (chemistry, physics, biology, engineering, etc), an experience that is enriching my education and stimulating my curiosity. Hopefully these inspiring circumstances will enhance my ability to contribute to the scientific *community.*

What has the PhD scholarship program brought you so far?

The MMI scholarship program introduced me to two vibrant and intellectually stimulating environments, the University of Melbourne and CSIRO, where I have the opportunity to meet world-renowned experts, access first-class facilities and attend international conferences! I am also learning the importance of finalising my research and delivering a result of the best quality possible, where all aspects and problems are analysed, understood and eventually solved.

Selected 2012 publications

Below is a selection of publications (journal and conference papers) relating to the MMI research themes and seed funding projects. They are ordered alphabetically by first author.



Best, J. P.; Yan, Y.; Caruso, F. 'The Role of Particle Geometry and Mechanics in the Biological Domain', *Advanced Healthcare Materials* 2012, 1, 35 (Inaugural Issue, front cover page).

Chandrawati, R.; Caruso, F. 'Biomimetic Liposome- and Polymersome-Based Multicompartmentalized Assemblies', *Langmuir* 2012, DOI: 10.1021/la301958v (feature article; front cover page).

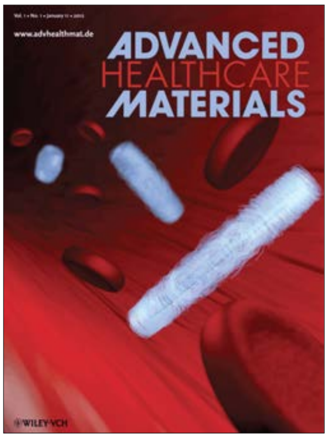
Chayabutra, S.; Kamolchote; K.; Kaewpracha, C., Ruengsirithanyakul, T.; Kaewpracha, A.; Wimolsai, N.; Tse, N. 'The Production and Deterioration of Artist Paints in Thailand', The Conservation of Material Culture in Tropical Climates 2012, Silpakorn University, Bangkok.

Chen, D.H.; Cao, L.; Hanley, T.L.; Caruso, R.A. 'Facile synthesis of monodisperse mesoporous zirconium titanium oxide microspheres with varying compositions and high surface areas for heavy metal ion sequestration', *Advanced Functional Materials* 2012, 22, 1966-1971.

Cui, J.; Yan, Y.; Wang, Y.; Caruso, F. 'Templated Assembly of pH-Labile Polymer-Drug Particles for Intracellular Drug Delivery', *Advanced Functional Materials* 2012, (featured in: Materials Views Wiley-VCH, July 2012).

Djalalian-Assl, A; Gómez,D.; Roberts, A.; Davis, T.J., 'Frequency-dependent optical steering from subwavelength plasmonic structures', *Optics Letters* 2012, 37, 20, 4206-4208.

Gomez, D.; Roberts, A.; Davis, T.J.; Vernon, K. C. 'Surface plasmon hybridization and exciton coupling', *Physical Review* 2012,B 86, 035411.



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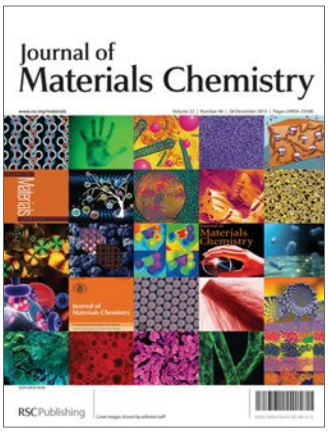
Kyi, C.; Schiesser, C.; Sloggett, R. 'NO. (nitric oxide) to biodeterioration', The Conservation of Material Culture in Tropical Climates, Silpakorn University, Bangkok.

Leung, M. K. M.; Hagemeyer, C. E.; Johnston, A. P. R.; Gonzales, C.; Kamphuis, M. M. J.; Ardipradja, K.; Such, G. K.; Peter, K.; Caruso, F. 'Bio-Click Chemistry: Enzymatic Functionalization of PEGylated Capsules for Targeting Applications', *Angewandte Chemie International Edition* 2012, 51, 7132 (featured as a 'Hot Paper').

Lewincamp, S.; Tse, N.; Sloggett, R.; Nel, P.; Scott. M. 'Using cross-disciplinary investigation to inform questions about an insecurely provenanced Middle Eastern manuscript', *Science in Society* 2012 (in peer review).



Morfa, A.J.; Gibson, B.C.; Karg, M.; Karle, T.J.; Greentree, A.D.; Mulvaney, P; Tomljenovic-Hanic, S. 'Single photon emission and quantum characterisation of zinc oxide defects', *Nano Letters* 2012,12 (2), 949-954.

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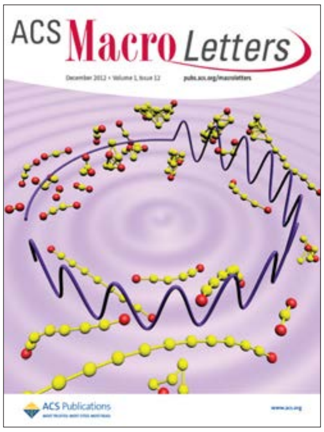

Nel, P.; Lau, D.; Braybrook, C. 'A closer analysis of old cellulose nitrate repairs obtained from a Cypriot pottery collection' in Symposium 2011: Adhesives and Consolidants for Conservation Research: Research and Applications – Symposium papers, 17-21 October 2011, Canadian Conservation Institute, Ottawa, online. Published 2012.

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Reid, L.; Tse, N.; Kyi, C.; Chayabutra, S. 'Mold Growth in Acrylic Paint Films in Tropical Climates', The Conservation of Material Culture in Tropical Climates 2012, Silpakorn University, Bangkok.

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Shimoni, O.; Postma, A.; Yan, Y.; Scott, A. M.; Heath, J. K.; Nice, E. C.; Zelikin, A. N.; Caruso, F. 'Macromolecule Functionalization of Disulfide-Bonded Polymer Hydrogel Capsules and Cancer Cell Targeting', *ACS Nano* 2012, 6, 1463.

Sidiroglou, F.; Nguyen, H.; Baxter, G.W.; Collins, S.F.; Roberts, A.; Davis, T.J. 'Modeling of Gold Circular Sub-Wavelength Apertures on a Fiber Endface for Refractive Index Sensing', *Photonic Sensors* 2012, 2, 271-276.

Stickland, A.D. 'A compressional rheology model of fluctuating feed concentration during filtration of compressible suspensions', *Chemical Engineering Science* 2012,75, 209-219.

Sun, K.; Zhao, B.; Murugesan, V.; Kumar, A.; Zeng, K.; Subbiah, J; Ouyang, J. 'High-performance polymer solar cells with a conjugated zwitterion by solution processing or thermal deposition as the electron-collection interlayer', *Journal of Materials Chemistry* 2012, 22, 24155-24165.

Yang, J.; Vak, D.; Clark, N.B.; Subbiah, J.; Wong, W.W.H.; Wilson, G. 'Organic photovoltaic modules fabricated by an industrial gravure printing proofer' *Solar Energy Materials and Solar Cells* 2012, 109, 47–55.

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Tan, S.Y.; Tabor, R.F.; Ong, L.; Stevens, G.W.; Dagastine, R.R. 'Nano-mechanical properties of clay-armoured emulsion droplets', *Soft Matter* 2012, 8, 3112-3121.

Tse, N.; Chayabutra, S. '20th Century Canvas Paintings: Developing conservation methodologies through an empirical, technical art history and materials analysis approach,' The Conservation of Material Culture in Tropical Climates 2012, Silpakorn University, Bangkok.

Yan, Y.; Such, G. K.; Johnston, A. P. R.; Best, J. P.; Caruso, F. 'Engineering Particles for Therapeutic Delivery: Prospects and Challenges', *ACS Nano* 2012, 6, 3663 (invited perspective).

Finance

The MMI receives core funding from the Deputy Vice-Chancellor (Research) (DVC(R)) each year to fund research-enabling activities, such as seed funding, scholarships, workshops and public events. This funding also provides for the MMI directorate salaries and operating costs. The MMI receives supplementary funding from the University - the DVC(R) and the Melbourne School of Engineering - for the technical activities. The breakdown of MMI's income and expenditure is detailed below.

INCOME		
Core University funding		992 250.00
Supplementary University funding (for technical support program)		242 000.00
Strategic University funding		20 000.00
Other internal funding		30 000.00
External funding		106 168.75
TOTAL		$1 390 418.75
EXPENDITURE		
Operating expenditure		529 257.63
Salaries	516 791.23	
Administration and other costs	12 466.40	
Research enabling expenditure		661 140.45
MMI administered funds		
Technical support program	179 759.96	
Partnership development	8 721.27	
Research events and promotions	25 460.02	
MCN Access Scheme - Pre-paid time	20 875.00	
Distributed funds		
Interdisciplinary Seed Funding	220 000.00	
PhD scholarships	65 856.00	
Strategic research support	50 000.00	
Workshop support	12 351.75	
Visiting fellows	17 384.63	
MCN Access Scheme - Merit-based time	4 125.00	
Journal cover publication support	4 987.41	
Theme support	37 353.16	
Other research support	14 266.25	
TOTAL		$1 190 398.08

Funding distribution

In 2012 the MMI distributed a total of $421 357 to University researchers to support interdisciplinary materials research activities. The management committee approves the MMI budget at the beginning of the year and determines the distribution of funds for large programs, such as the Interdisciplinary Seed Funding (IDSF) scheme and strategic funding.

Schemes

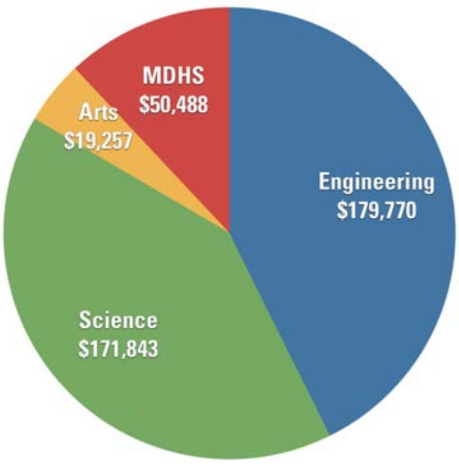
The largest proportion of the funds provided by the MMI to the materials research community are distributed as seed grants in the IDSF scheme. The Institute has also established smaller funding schemes (up to $20K) to support the MMI research themes and to assist University materials researchers with costs including those incurred by journal cover publication, visits by collaborators and events (see p9-12 for details).

Distribution

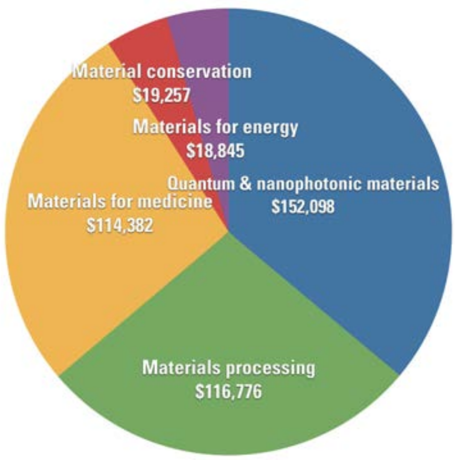
In 2012 MMI funds were distributed to researchers in seven departments across four faculties. The Faculty of Science and the Melbourne School of Engineering were allocated most of the funding, mainly as IDSF grants. These seed grants supported projects falling under three of the MMI research themes: Quantum and nanophotonics materials, Materials processing and Materials for medicine.

Seed funding was provided by the University's central allocation for the Materials for energy and Materials conservation themes, along with smaller amounts from the MMI for other activities. With new leadership in the Materials for energy theme (Dr David Jones) and the recent creation of Materials conservation theme, we expect that funding to these themes will increase in 2013.

Distribution of funds by faculty



Distribution of funds for each MMI research theme



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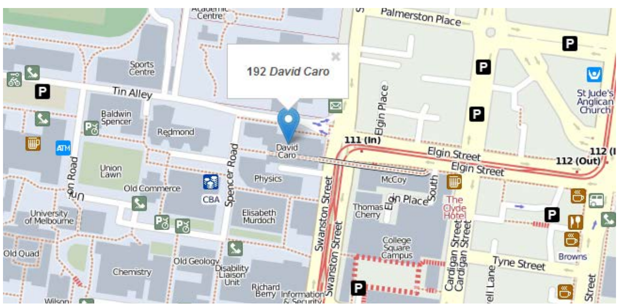


Back cover: journal covers for which authors received MMI financial support. From left to right:

First row:

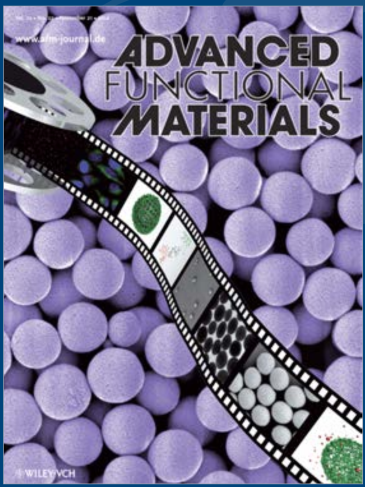
1. Prof Frank Caruso et al., 'Templated Assembly of pH-Labile Polymer-Drug Particles for Intracellular Drug Delivery', *Advanced Functional Materials* 2012, 22, 22, 4718–4723.
2. Prof Frank Caruso et al. 'Bio-Click Chemistry: Enzymatic Functionalization of PEGylated Capsules for Targeting Applications', *Angewandte Chemie International Edition,* 2012, 51, 29, 7132–7136.
3. A/Prof Rachel Caruso et al.,'Spiky Mesoporous Anatase Titania Beads: A Metastable Ammonium Titanate-Mediated Synthesis', *Chemistry - A European Journal* 2012,18, 43, 13762–13769.

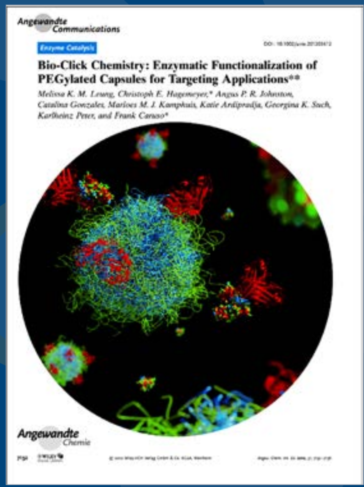
Second row:

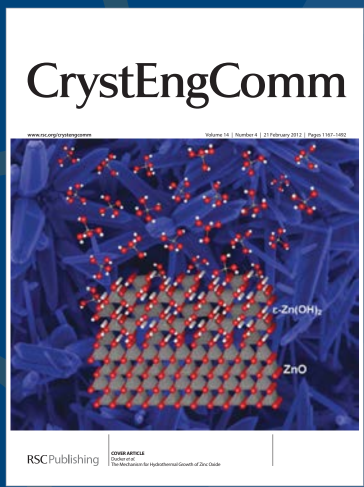
1. Prof Greg Qiao et al., 'Novel drug carriers: from grafted polymers to cross-linked vesicles', *Chemical Communications* 2013, 49, 1, 33-35.
2. Prof George V. Franks et al., 'The Mechanism for Hydrothermal Growth of Zinc Oxide', *CrystEngComm* 2012, 14, 4, 1232-1240.
3. Prof Greg Qiao et al., 'Factors influencing the growth and topography of nanoscale films fabricated by ROMP-mediated continuous assembly of polymers', *Polymer Chemistry* 2013, 4, 68-75.

Third row:

A/Prof Raymond Dagastine et al., 'Compound sessile drops', *Soft Matter 2012,* 8, 43, 11007–11194.







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