© The Melbourne Materials Institute. Enquiries for reprinting information contained in this publication should be made through: materials-info@unimelb.edu.au
Melbourne Materials Institute
The University of Melbourne
Victoria 3010
t +61 3 8344 6415
f +61 3 9347 4783
Editor: Gaby Bright, MMI staff
Design: Jeanette Dargaville
Every attempt was made to ensure that the information in this publication was correct at the time of printing. The University reserves the right to make changes as appropriate.
For further information visit:
http://www.materials.unimelb.edu.au

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 encapsulate 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 involved 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 information can be deduced from this image. Credit: Q. Besford, A. Gray-Weale.

Third row:
1. Prof David Awschalom (UCSB) talking to fellow researchers and students from the University. Credit: Casamento Photography.
3. MMI event. Credit: Casamento Photography.
4. False colour high-resolution image of nanocomposite showing metal nanoparticles 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.
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

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Message from the chair</td>
<td>1</td>
</tr>
<tr>
<td>Director’s report</td>
<td>2</td>
</tr>
<tr>
<td>Governance, management and reporting</td>
<td>3</td>
</tr>
<tr>
<td>2013 in review</td>
<td>5</td>
</tr>
<tr>
<td>CoE, CRC and ARC review</td>
<td>5</td>
</tr>
<tr>
<td>Achievements and Awards</td>
<td>6</td>
</tr>
<tr>
<td>Research funding and support</td>
<td>7</td>
</tr>
<tr>
<td>ARC outcomes</td>
<td>8</td>
</tr>
<tr>
<td>2013 events</td>
<td>9</td>
</tr>
<tr>
<td>2014 in review and events</td>
<td>10</td>
</tr>
<tr>
<td>MMI future</td>
<td>11</td>
</tr>
<tr>
<td>Materials PhD Program</td>
<td>12</td>
</tr>
<tr>
<td>Researcher profiles:</td>
<td>13</td>
</tr>
<tr>
<td>A/Prof Robyn Sloggett</td>
<td>13</td>
</tr>
<tr>
<td>Dr David Garrett</td>
<td>14</td>
</tr>
<tr>
<td>Ms Christine Browne</td>
<td>15</td>
</tr>
<tr>
<td>MMI research themes: overview</td>
<td>16</td>
</tr>
<tr>
<td>Materials conservation 2013-2014 highlights</td>
<td>17</td>
</tr>
<tr>
<td>Materials for energy 2013-2014 highlights</td>
<td>18</td>
</tr>
<tr>
<td>Materials for medicine 2013-2014 highlights</td>
<td>19</td>
</tr>
<tr>
<td>Materials processing 2013-2014 highlights</td>
<td>20</td>
</tr>
<tr>
<td>Quantum and nanophotonic materials 2013-2014 highlights</td>
<td>21</td>
</tr>
</tbody>
</table>
Interdisciplinary Seed Funding scheme

Nanoscale Pixel CMOS sensor
Characterisation of nitinol for fabrication of intravascular stent electrode for novel brain-machine interface
Cybernetic diamond for targeted neuronal growth
High performance composite textile using shear thickening fluid
A novel neuroscience-inspired many-state logic element for artificial brain tissue replication and low power, massively parallel information processing, sensing and control
Structure and function dynamics in remodelling of airway smooth muscle (ASM) cells through quantitative imaging
Multiple sensors for the in situ, non-invasive investigation of works of art
Quantum levitation and confined diffusion of colloidal particles
Multi-scale porous titanium diboride materials for battery cathodes
From pariah to messiah: using the mast cell to deliver nanoparticle-derived bioactive molecules

MCN Access Scheme

Platform Development Pilot Program

Nanomaterials Characterisation
Advanced Fluorescence Imaging
Nanofabrication
Platform outlook

2013 finance
2014 finance
MMI team
Contact details
Chair’s welcome

2013 and 2014 have seen the MMI consolidate the efforts of previous years.

Major achievements have included the extension of funding for the platform support program. The platform, started as a pilot by the MMI in 2012, received funding for a further three years. This is a fabulous endorsement of the MMI’s efforts. Excellence in materials research was recognised on the national stage when MMI researchers received three prizes at the annual Eureka awards. The MMI has also held four excellent national and international workshops over the past 18 months: Nano@Melbourne; the MMI’s annual research workshop; OzCarbon 2013; and Advanced Nanomaterials for Energy (ANE). The keynote speaker at the ANE workshop was Professor Eric Isaacs, then head of Argonne National Labs in the US and now Provost of the University of Chicago. During his visit he also gave a public lecture to a packed audience at the University.

Whilst important, collaboration and research excellence are not enough. Research needs to have impact that is felt throughout society, economy and the environment. The MMI, through activities such as the bionic eye project and engagement with organisations such as IBM, DSTO and the Australian Industry Group, has endeavoured to ensure that the materials research undertaken at the University of Melbourne has impact.

The current MMI will not continue in its current form after 2014, however the new Melbourne Materials Initiative will complement the continued platform support program and an anticipated Materials PhD program. On behalf of the MMI Advisory Board I congratulate the Director and his team on the achievements of the Melbourne Materials Institute over the years and the broad range of support, engagement and outreach that the MMI has provided the materials community.

I have enjoyed chairing the MMI Advisory Board and commend to you this final Annual Report, a summary of the excellent research supported and initiated by the Melbourne Materials Institute in 2013 and 2014.

Calum Drummond
Chair, MMI Advisory Board
Group Executive, CSIRO Manufacturing, Materials and Minerals (2013)
Deputy Vice-Chancellor (Research & Innovation) & Vice-President, RMIT University (2014)
Director’s report

As a result of the University’s decision to reshape the ways it supports its community of materials researchers, the Melbourne Materials Institute closed on June 30, 2014, and this will be its final report. Whilst we are sad to see the closure of the MMI, we are also proud of our accomplishments and encouraged that many of the programs that we have championed will continue under the banner of the Melbourne Materials Initiative.

It has been a great honour and privilege to serve as the Director of the MMI. I have enjoyed immensely the opportunity to take a global perspective in promoting and supporting materials research across the breadth of the academy, and to understand the reach of materials research in faculties in arts, medicine, science and engineering. It has been an incredible privilege to meet so many researchers and get to understand a little of their passion for pushing the boundaries of what is possible in fields ranging from quantum sensing to tissue engineering.

The MMI has a great story to tell of successes over the past five years of its operation. We are proud of our accomplishments which include: support for the development of the next generation of materials researchers through a range of PhD scholarship programs, many in collaboration with external partners; the establishment of the Defence Science Institute, an outcome of the close relationship between the MMI and the DSTO; the establishment of the MMI Platform support program which provides instrument specific expertise to University of Melbourne and external researchers; support for more than 20 interdisciplinary research projects through the MMI seed funding program, some of which have led to external recognition in Eureka and other prizes; the realisation of ‘bionic eye' retinal implants as part of Bionic Vision Australia; and facilitating the successful bid for the $26M ARC Centre of Excellence in Convergent Bio-Nano Science and Technology.

I would like to take this opportunity to express my personal and heartfelt thanks to the present and past staff of the MMI including MMI manager, Ms Gaby Bright, deputy director Associate Professor Ray Dagastine, project officer Ms Lillian Tan, technical support coordinator Dr Lauren Hyde, platform support officers, Benjamin Hibbs, Marta Redrado Notivoli, and Dan Smith, finance officer Hana Crisp and industry partnerships manager Dr Noel Dunlop. I am also grateful to past staff members who contributed to the success of the institute including past institute manager, Andrew Tierney, past communications officer Annabelle Pontvianne and past technical manager Irving Liaw. I would also like to express my appreciation to members of the Management Committee and the Advisory Board for their support. And of course I would like to thank all of our stakeholders, for their participation and collaboration over the past five years.

Materials are the key to a sustainable society. Advances and innovation in materials science and technology underpin solutions to meeting the challenges we face in water, health and energy. In previous centuries the development of concrete and steel enabled us to build skyscrapers and the development of pure and doped silicon ushered in the information age. Now, more than ever, we need innovation in materials to address problems ranging from drug delivery and tissue regeneration to desalination and carbon capture and storage. Whilst the MMI is closing, the core mission of using advanced materials for the betterment of society remains.

Wishing all those associated with the MMI every success in their future endeavours.

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 is responsible for day-to-day management and provides strategic advice to the director.

2013 saw a number of staffing changes. Associate Professor Ray Dagastine was appointed MMI’s Deputy Director. As the MMI’s focus shifted towards industry and external engagement Dr Noel Dunlop was recruited and the position of Communications Officer, held by Ms Annabelle Pontvianne, ended.

The management of the Technical Support Program changed with Dr Lauren Hyde taking over from Mr Irving Liaw. As planned in 2012, a third platform was established at the Melbourne Centre for Nanofabrication, with technical support provided by Mr Dan Smith.
Management committee

The management committee provides 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 met four times in 2013: 28 March, 26 June, 25 July, and 2 October.

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;
- 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;
- Prof Peter Taylor, Associate Dean (Research), School of Mathematics and Statistics.
Centre of Excellence
In December 2013 the Australian Research Council announced $26 million funding for a Centre of Excellence (CoE) in Convergent Bio-Nano Science and Technology. The CoE will undertake research to better understand and control the interface of materials with biological systems with four focus areas: delivery systems; imaging technologies; biosensors and diagnostics; and vaccines.

The MMI had been supporting the CoE application development since 2011, when the Nano-In-Medicine symposium was held in conjunction with the Bio21 Cluster. Melbourne University’s participation in the bid has been led by Professor Frank Caruso, from the Department of Chemical and Biomolecular Engineering, along with Professors Edmund Crampin (Electrical and Electronic Engineering) and Stephen Kent (Immunology). The Centre will be led by Monash University, following direction from the ARC to merge the Melbourne and Monash applications at Expression of Interest stage. In addition to the Universities from Victoria, the CoE brings together UNSW, UQ, UniSA, CSIRO and ANSTO, along with eight international institutions.

ARC review - BVA
On 13 February the ARC undertook a review of the Bionic Vision Australia project. This included a briefing with senior researchers and visits to the various laboratories, including the MMI facilities at Physics. The review went well though the final report will not be provided for some time.

MMI Platform Development Pilot Program
In September, Dr Lauren Hyde started as the Technical Support Coordinator of the MMI Platform Program. Lauren reports to MMI Deputy Director A/Prof Ray Dagastine and manages three Technical Support Officers. Previously Lauren managed the Vibrational Spectroscopy facility at the University of Sydney and was a beamline scientist on the infrared microspectroscopy facility at the Australian Synchrotron. She has experience with many surface topography and chemistry preparation methods as well as surface analysis experience including infrared microscopy, atomic force microscopy (AFM) and scanning electron microscopy (SEM). She recently completed her PhD studies, with her thesis on “Preparation of gradient surfaces for the analysis of cell-surface interactions”.

CRC in Innovative Manufacturing
Following extensive planning and discussions with the MMI Advisory Board Chair, Calum Drummond (Group Executive, CSIRO), the MMI has led the development of a bid for a Collaborative Research Centre (CRC) in Manufacturing Industry Innovation. The bid has four partners: the University, CSIRO, Australian Industry Group and ASFA, the Association of Superannuation Funds of Australia. The bid was shortlisted for interview, which took place on 12 November in Canberra. The outcome of the application was that the Minister requested that the MMI sponsored bid join forces with the Advanced Manufacturing CRC rebid to submit a combined proposal. The combined proposal, now called the Innovative Manufacturing CRC was interviewed in Canberra on 24 June. An announcement is expected shortly.

Key MMI researchers receiving Eureka awards. Pictured left: Prof Frank Caruso, Prof Lloyd Hollenberg and Dr Yan (Annie) Yan. Pictured right: Dr Tuan Ngo receiving the DSTO Eureka prize for Outstanding Science in Safeguarding Australia.
Achievements and Awards

Eureka Awards

The endeavours of key MMI researchers were recognised with awards in the 2013 Australian Museum Eureka Prizes. The following awards were received:

• CSIRO Eureka Prize for Leadership in Science: Professor Frank Caruso. Prof Caruso is the leader of the MMI Materials for Medicine Theme. In addition to providing seed funds for projects that Prof Caruso has collaborated on, the MMI has supported a Centre of Excellence bid led by Prof Caruso.

• UNSW Eureka Prize for Excellence in Interdisciplinary Scientific Research: Quantum Bio-probes, Professor Lloyd Hollenberg and team. Prof Hollenberg was previously the leader of the MMI Quantum materials theme and he received MMI seed funding in 2009-10 for a project on "Quantum decoherence imaging for biological systems" that led to this award.

• DSTO Eureka Prize for Outstanding Science in Safeguarding Australia: Defence Materials Technology Centre, with collaborators including Dr Tuan Ngo and Professor Priyan Mendis from the University of Melbourne. Dr Ngo and Prof Mendis received seed funding from the MMI to continue their research in this area – “High Performance Composite Textile Using Shear Thickening Fluid”.

Other MMI members were amongst the Eureka Prize finalists:

• UNSW Eureka Prize for Excellence in Interdisciplinary Scientific Research: Bionic Vision Australia

Visitors

Adam Bandt, MP, visit

On 10 April, the MMI hosted a visit by Dr Adam Bandt, Greens MP for the Federal seat of Melbourne, to the Bionic Eye project. During the visit he met with Bionic Vision Australia Chairman, Professor David Pennington, High Acuity Device project leader Dr Hamish Meffin and MMI Director, Professor Steven Prawer. Following a tour of the laboratories and extensive discussion about the technology developed and the future funding arrangements, Dr Bandt met with postdoctoral and PhD students working on the project.

DARPA visit

On 20-21 May, the Defence Science Institute hosted a visit by DARPA (US Defense Advanced Research Projects Agency), with a symposium on Neural Interfaces. The MMI jointly hosted the symposium dinner and MMI Director, Professor Steven Prawer, presented at the Symposium on MMI research.

DIICCSRTE visit to BVA

On 30 July, a delegation from DIICCSRTE (Department of Industry, Innovation, Climate Change, Science, Research and Tertiary Education) met with senior members of BVA, including Chairman David Pennington, and visits to the various laboratories. The following representatives composed the delegation:

• Helen Atkinson, Pharmaceuticals & Health Technologies, Industry and Innovation Division
• Julia Evans, General Manager Pharmaceuticals and Transformative Industries Branch:
• Mr Peter Lunn from the Pharmaceuticals & Health Technologies Section
• Dr June Fan from the Pharmaceuticals & Health Technologies Section

MMI appointments

A/Prof Ray Dagastine, Department of Chemical and Biomolecular Engineering, was appointed Deputy Director of the MMI. The new role of Industry Partnerships Manager was filled by Dr Noel Dunlop, who joined the MMI with experience at CSIRO, Orica and other organisations.
2013 in review - research funding and support

Postgraduate research

IBM-MMI PhD Scholarship Program

A new PhD program with IBM was launched by the MMI in November. The program provides the students who participate with supervisors at both the University of Melbourne and at the IBM Almaden Research Laboratories in San Jose, USA. Each student will spend a significant period of time at Almaden, undertaking industrially relevant research and experiencing a non-academic research environment. The preliminary list of research projects on offer includes nanoparticle drug delivery modelling, filtration membranes and battery cathodes. Supervisors at the University of Melbourne are drawn from across the faculties of Science and Engineering and for some of them it will be their first time collaborating with IBM.

Materials PhD Program

The MMI has been developing an interdisciplinary PhD program, which would span the faculties of Science, Engineering and Medicine. It would provide an interdisciplinary, cohort experience for materials science PhD students. The Materials PhD Program is being considered as part of a small suite of interdisciplinary, cross-faculty, PhD programs.

The MMI hopes that the program, which will go to the University's Academic Board later in 2014, will serve as a pilot to demonstrate what can be achieved in terms of increasing both the quality and quantity of PhD students both entering and graduating from our postgraduate programs.

Seed funding

In 2013 the Melbourne Materials Institute seed funding scheme was broadened to incorporate research projects that build on, or develop, engagement with external parties as well as those that will generate new research collaborations within the University. Priority was given to research teams that involved Early Career Researchers. A record number of 37 applications were received and assessed by the multifaculty and multidisciplinary selection committee. A total of $220,000 in funding was distributed to eight projects across five departments in three faculties. The projects will investigate materials solutions to a broad range of challenges, from antibacterials coatings in hospitals to future food shortages to salvaging limbs from bone cancer.
ARC outcomes

2013 and 2014 saw success for materials researchers in the Australian Research Council (ARC) funding rounds. Over $12 million in grant funding was secured by University of Melbourne materials researchers.

Laureate Fellowship

Prof Lloyd Hollenberg in Physics was awarded an Australian Laureate Fellowship for 2013 by the ARC. This prestigious award goes to outstanding, world-class researchers who play a significant leadership and mentoring role in building Australia's internationally competitive research capacity. Professor Hollenberg was previously the leader of the MMI's Quantum and nanophotonic theme.

DECRAs

The Discovery Early Career Researcher Awards (DECRAs) provide support for promising early career researchers (ECRS). Five materials focused ECRs from across the University were awarded DECRAs, worth $375,000 each, to work on projects from a diverse range of areas such as biomedicine and nanophotonics.

- 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 Yan Yan (Chemical and Biomolecular Engineering) - Cellular dynamics of nanoengineered particles.

Centre of Excellence

As flagged earlier, the MMI provided support to the successful application for an ARC Centre of Excellence (CoE), broadly in the field of nanomedicine. Professor Frank Caruso, leader of the MMI's material for medicine theme, is the Deputy Director of the ARC CoE in Convergent Bio-Nano Science and Technology, to be based at Monash University. The CoE received $26 million in funding for seven years and over $6 million of this will come to the University of Melbourne.

Other ARC excellence

In addition to the successes outlined here there were further 'wins' for materials researchers in the Discovery Project, Linkage, Infrastructure, Equipment and Facilities (LIEF), and Industrial Transformation Research Hub funding schemes.
2013 events

Technical Seminar
On 15 April the MMI hosted a technical seminar by the Melbourne Centre for Nanofabrication (MCN). Following an introduction by MCN Managing Director Dwayne Kirk, University of Melbourne researchers spoke of their experiences using the facilities and the benefits to their research. MMI Characterisation Platform leader A/Prof Ray Dagastine provided information to attendees about how they can access the facilities and the support provided by the Melbourne Materials Institute.

Nano@Melbourne
As part of his new role as MMI Deputy Director, A/Prof Ray Dagastine coordinated the Nano@Melbourne workshop on June 6. The workshop was attended by 56 people, including graduate students, research staff and senior academics, who came to hear the broad range of talks. The afternoon discussion covered the areas of nanoscience and modelling, nanocharacterisation and nanofabrication. The group discussion captured many of the issues and needs of researchers in these areas, and provided an opportunity for researchers to interact with people that they otherwise wouldn’t meet. For some, it also exposed them to the expertise and infrastructure available through the MMI Platform Development Pilot Program, as well as the MCN. Sach Jayasinghe, the Research Infrastructure Strategy Advisor, participated and evaluated many of the comments and suggestions from the researchers on the day.

MMI Annual Research Workshop
On Thursday 22 August the Annual Materials Workshop was held at Graduate House. Leo Hyde, the Director of Research and Development at DuPont Australia, presented the plenary talk. Workshop topics included polymers, optical materials and methods, materials conservation, modelling, bionics and materials for applications. A total of 20 presentations were made throughout the various sessions. There were over 100 participants, including representatives from Agilent, the Art Gallery NSW, Bionics Institute, CSIRO, Deakin University, General Electric, IBM, National Gallery of Victoria, NICTA, Orica, Pental, and the Reserve Bank of Australia.

OzCarbon
From 1-3 December 2013 the second OzCarbon conference was held in Melbourne. The local organising committee was chaired by MMI Director Prof Steven Prawer, and was assisted by the MML. The conference includes the annual meeting of the Australian Carbon Society and brought together people from across Australia undertaking carbon research: from graphene to carbon capture and storage. The two day conference was attended by 80 delegates and included $15,000 of sponsorship from industry and academia.

Question time during a presentation at OzCarbon
Wine and Cheese Events

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 2013, the MMI held two Wine & Cheese afternoons.

At the first Wine & Cheese event on 22 March (‘What funding is available to me?’) Adrian Collins and Melinda Herron from Melbourne Research provided an overview of available funding opportunities. This comprehensive summary outlined the support for travel, research and collaboration. They provided information to approximately 35 early and mid-career researchers on how to get advice in the planning and application for funding.

The second Wine & Cheese event on 21 August (‘Find out more about PFPC and how to better engage with Industry’), Prof Geoff Stevens presented an overview of the Particulate Fluids Processing Centre and how it engages with industry. The event provided an opportunity for early and mid-career researchers to meet with industry representatives. Attendees included representatives from Museum Victoria, Rio Tinto, Pental, Glasko Smith Kline, CSIRO and General Electric.

Argonne National Labs Visit

Dr Eric Isaacs, Director of Argonne National Laboratory (USA), and Dr Peter Littlewood, Associate Director of Argonne, visited Melbourne from 28-31 January. The visit was hosted by the Melbourne Materials Institute, and included a tour of the Melbourne Centre of Nanofabrication and of the Australian Synchrotron.

On 30 January Dr Isaacs gave a public lecture on The developments in materials to meet alternative energy challenges. The lecture was followed by a panel discussion with Dr Isaacs, Tony Wood of the Grattan Institute, Prof Andrew Holmes (UoM, President-elect of the Australian Academy of Sciences) and, Adam Bandt, Deputy Leader of the Greens. Over 400 people attended the event with much positive feedback on the range and depth of discussion. The public lecture was followed by a dinner for speakers and guests.

On the final day of the visit was the Advanced Nanomaterials for Energy workshop. Dr Isaacs was the keynote speaker at this technical workshop, held at Graduate House. Dr Littlewood also gave a presentation along with 10 others, including international speakers.

Both Dr Isaacs and Dr Littlewood were impressed by the research undertaken at the University of Melbourne and are keen to pursue future research collaborations.

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

Dr Eric Isaacs, Director of Argonne National Laboratory, delivering his public lecture at the University of Melbourne.
MMI Future

Materials Hallmark Initiative
The MMI was founded in 2009 and in mid 2014 the Institute will transition to a new Hallmark Initiative, to be called the Melbourne Materials Initiative. This evolution is part of the University’s strategy for internal research investments. Many activities currently undertaken by the MMI will be taken over by the new Melbourne Materials Initiative. It will provide a portal into the University, it will hold researcher networking events, and it will have an initial focus on strengthening collaborations in materials and devices for medicine and in materials for energy.

Other major activities of the Institute will continue under the broad umbrella of the new Melbourne Materials Initiative. The pilot infrastructure platform program will now be supported under the University of Melbourne’s Collaborative Research Infrastructure Program that commenced in 2013. Pending approval from the Academic Board, the MMI PhD scholarship program will be developed into a multi-faculty materials science and engineering PhD program through which participating postgraduates will undertake coursework as well as industry placements and mentoring. This will be one of the new suite of PhD programs being progressively introduced at the University.

Achievements of the Melbourne Materials Institute
When announcing the transition of the Melbourne Materials Institute to an Initiative, the Deputy Vice-Chancellor listed the following achievements of the MMI: showcasing the University’s strengths in materials research; enhancing the accessibility of the University’s materials research and researchers; strengthening existing collaborations between researchers and forging new internal and external links; creation of research infrastructure platforms; and opening up of major new funding opportunities for the University.

Feedback on the end of the MMI
On hearing about the end of the MMI, in its current form, much positive feedback on the last five years was received:

“It is a great shame that MMI is coming to an end as it has been a jewel in the Institute program. I have benefited from its inception as I have had grants with Prof Caruso, Dr Connal and I am submitting a NHMRC grant with Dr Yan and Prof Caruso this year. I have also on going collaborations with Prof Frank Caruso, Prof Greg Qiao, Prof Andrea O’Connor and Dr Luke Connal, I co-supervise 3 PhD students through these collaborations and have two publications to date with 5 being submitted and 4 others in preparation. All of this has come from meetings and events by the MMI. I am sorry that I will not be there to celebrate the wonderful work done by MMI and to hear what is coming next.”

Dr Neil O’Brien-Simpson, Melbourne Dental School

“It’s really sad to hear the news but I just wanted to email you to let you know how grateful I am for having the opportunity to be a part of MMI-CSIRO PhD program. Through this program, I gained a valuable supervisor from CSIRO who has helped with my PhD. The scholarship, as well, alleviated a financial burden, which helped me concentrate on my research.

And thank-you!”

Jordanna Master, MMI-CSIRO PhD Scholarship recipient

“I would like to thank you and MMI for the considerable support for our research. The seed funding, PhD scholarship, MCN time and the workshops organised by MMI have helped us a lot. It has generated new cross disciplinary areas for our lab, and also led us to many new collaborators.”

Peter Lee, Melbourne School of Engineering
In 2013 the MMI began development of a pilot Materials PhD Program.

In 2014 the Program was endorsed by the Melbourne School of Graduate Research and will be considered by the Academic Board for formal incorporation into the University’s offerings.

The PhD Program will provide an enriched postgraduate research experience than is currently offered to students and will be more relevant and responsive to the needs of future employers. It has been designed to ease the transition from academia to industry and equip our graduates with the breadth and transferable skills that are not built into the current programs. It has been tailored to:

• Reflect the reality of employment pathways, ensuring that PhD graduates have skills and attributes to go beyond those of specialised technicians;
• Ensure that the University’s PhD program is competitive and will continue to attract the best and brightest candidates;
• Improve the overall quality of research within the University; and
• Train a cohort of graduates with a strong sense of belonging and commitment to the University.

The proposed Materials PhD Program has a range of features:

• A cohort experience: bringing together the materials PhD students from the host departments across the University, for seminars and networking events.
• Integrated coursework: students will be able to select coursework to supplement their materials science or engineering base. These subjects could include: managing innovation and entrepreneurship; entrepreneurial finance; business tools: money, people and processes; or business and professional communications.
• Mentoring: in addition to the normal supervision provided by academic experts, the students will be assigned a mentor to support the broader aspects of a PhD experience. To supplement the mentorship, students will have access to statistical services and, where required, English language assistance.
• Industry linkage and travel opportunities: by providing internships, either domestically or internationally, students get to experience the application of research outside academia. Potential employers benefit by getting a first hand exposure to the capabilities of University graduates.

We hope that, despite the formal end of the MMI, the Program will be run in the next few years and provide an exciting new opportunity for graduate Students.

Left: These students, part of the MMI-CSIRO PhD Scholarship Program, experienced some of the aspects of the proposed Materials PhD Program: the cohort experience; mentorship; and placement within a non-academic research environment.

L-R: Aaron Song (Chemistry), Jordanna Master (Physiology), Fabio Lisi (Chemistry), Terence Hartnett (Chemical and Biomolecular Engineering), Ben Yap (Chemical and Biomolecular Engineering) and Israr Saeed (Mechanical Engineering).
Researcher profiles:  A/Prof Robyn Sloggett
Director, the Centre for Cultural Materials Conservation

‘The incorporation of Australian Indigenous knowledge into materials related science will open up new topics, but more importantly new ways of thinking about these topics.’

How would you describe what you do?
Conservation is a discipline that is concerned with understanding the construction and degradation cultural material and how best to preserve the physical, intellectual and cultural integrity of this material. With a focus on both the material and the cultural, cultural materials conservation requires complex interdisciplinary teams that also have strong cross-cultural engagement and understanding. My current interest centres on partnerships with Australian Indigenous communities to understand how shared knowledge programs can build skills across a range of disciplines in the University. I am also heavily involved in research, and practical outcomes relating to art fraud; an area that also requires a strong collaborative and interdisciplinary framework, working across the sciences, humanities, policing and the law.

What are the outcomes or applications that may result from your research?
The main aim of my research is to secure the preservation of cultural material that is endangered, and to ensure an authentic cultural record is passed on into the future.

What do you hope to achieve in the next few years?
The recent gift from the Cripps Foundation, which supports new laboratories and a new Chair in Cultural Materials Conservation, has substantially altered what it will be possible to achieve at the University of Melbourne in the immediate future. By the end of 2014 Materials Conservation will have purpose-built teaching and research spaces that will enable Masters by Coursework and Research Higher Degree students to much more easily pursue their research. Over the next few years, therefore, I am working with our partners in the US, Southeast Asia, China, Timor-Leste and the Pacific, and in Aboriginal communities in Australia to consolidate our existing research platforms in materials characterization and analysis, degradation mechanisms, conservation of materials in tropical climates, conservation in communities, and art authentication.

What significant developments do you see in your field in the next 5 to 10 years?
The incorporation of Australian Indigenous knowledge into materials related science will open up new topics, but more importantly new ways of thinking about these topics. This will have major impacts across Chemistry, Physics, Earth Sciences, Botany, Zoology, and other related areas. I can also see significant strides being made in our understanding of degradation and deterioration mechanisms and ways to manage and ameliorate these, particularly in tropical and subtropical climates. Our current work on art forensics is making an important contribution to securing an authentic cultural record in Australia, and within the decade expect we will be in a position to fingerprint individual sources quickly and with a high degree of reliability. New media and digital technology present some exciting opportunities for knowledge sharing and knowledge exchange, particularly with remote communities and partners overseas.

If you weren’t a researcher what would you do?
There’s not much else I’d rather be doing. The wonderful aspect of cultural materials conservation is that it can be a research-based scientific enquiry, or an applied activity treating a particular object. As a Centre director I have much more administrative work than I care to think about so the idea of being back at the bench, meticulously piecing together a fractured paint surface is extremely attractive. So perhaps I wouldn’t do anything different; I’d just choose to do what I do - differently.
Dr David Garrett  
Research Fellow, Bionics Institute, St. Vincents Hospital

‘The experience of cochlear implant users will continue to improve. Retinal implants will proliferate and visual acuity provided by these implants will increase.’

How would you describe what you do?
I design and test new electrodes for use in neural interface devices. My focus is on devices that can be fully implanted (similar to cochlear implants). These devices sometimes record action potentials from the firing of nerves or they can stimulate nerves to recreate sensation such as hearing, vision or touch.

Tell us about one of the main challenges you are currently trying to solve?
The current generation of implants, in particular those with a recording function generally exhibit a rapid decay in sensitivity due to the body’s ability to encapsulate foreign objects. The challenge is to fabricate devices that possess mechanical and chemical properties so similar to the target neural tissue that the body does not recognise the implant as foreign.

What are the outcomes or applications that may result from your research?
Devices that can coexist with the body without causing an immune response provide the conduit by which we can communicate reliably with the central or peripheral nervous system. Long term, stable recordings from peripheral nerves could serve to control a prosthetic limb and sensors in the prosthetic limb could activate stimulating electrodes, providing sensory feedback. Stimulation in the brain already provides relief from the symptoms of Parkinson’s disease and mood disorders and the success of cochlear implants is well known. Smaller, targeted, more flexible devices will provide improved performance in terms of stimulation resolution, power savings, long term reliability and consistency of performance.

What do you hope to achieve in the next few years? In the rest of your career?
Right now I’m just enjoying living with my family in Melbourne, the freedom of being on my own grant and the experience of working with my first PhD students. Beyond the next few years - who knows. Science was not my first career and I’ve always made progress by doing what needs to be done today as well as I can do it, treating everybody well, and having as much fun as I can. Hopefully opportunities will present themselves and I’ll be astute enough to spot them when they do.

What significant developments do you see in your field in the next 5 to 10 years?
The experience of cochlear implant users will continue to improve. Retinal implants will proliferate and visual acuity provided by these implants will increase. Implants for control of conditions such as epilepsy, Parkinson’s disease and chronic pain will become common place. Maybe in the next decade implants for uses other than medical will become a reality. These could be military in nature, functional or recreational.

In your opinion, what are the main ingredients for successful research collaboration?
Delivering on promises and having the attitude that outputs are for the benefit of all involved. Collaborations serve to accelerate the science and in the current model we want them because it increases our outputs. So in a nutshell; do the work, publish the results and promote your collaborators.

What do you do in your free time?
Free time is mostly taken up with the business of raising children now which I find as enjoyable as it is rewarding. My favourite sports team is the Under 12 Werribee Giants baseball team and I have a season ticket directly behind the dugout. I do have to bring my own chair however.
What are you researching for your PhD?
My research focuses on the various interactions and forces experienced between bubbles. I’m looking at several different types of forces and this involves using typical instrumentation and developing experimental set ups for more custom measurements.

What are the outcomes or applications that may result from your research?
Bubble and droplet behaviour is important in many products such as paint, pharmaceuticals and food products such as ice creams, milk foams and salad dressing. Having a deeper understanding of the fundamental factors that dictate their interaction lead to improvement in the products we purchase and use every day.

What attracted you to your research field?
I was attracted to colloid interactions and surface chemistry due to the fact that these small scale interactions play a vital role in many products that we all use daily, but they are still not fully understood.

Do you hope to continue in academia or a career outside academia? Still in research?
I would like to pursue a career in research when I complete my studies.

What significant developments do you see in your field in the next 5 to 10 years?
I think the field will continue to grow and expand into areas that previously were not typically known for surface science such as biological and medicinal research and further develop technology driven studies.

What role do you think science has to play in society?
Science plays a vital role in our fundamental understanding of the world and allows us to have our current way of life. I think people underestimate the importance of science as without it there would not be the medications, major infrastructure and food availability that we currently experience.

If you weren’t a scientist what would you do?
I would probably be school teacher. I like to encourage people to learn as it essential for a well rounded society.

What do you do in your free time? Or What is the personal or academic achievement you are most proud of?
In my free time I am involved in Girl Guides as a Unit Leader and I also enjoy playing classical guitar.
MMI research themes: overview

Most materials research at the University of Melbourne is represented by the MMI under five themes.

**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.
Partnerships both within Australia and internationally continue to strengthen. In China Memoranda of Understanding for a five year research programs on archaeological material have been signed with partners, Zhengzou University, Henan Provincial Institute of Cultural Heritage, and Shaanxi Province Institute of Archaeology. In Australia the Two-Way Learning Partnership with the Warmun Art Centre has been signed, with ochre as an agreed initial area of research. Dr Petronella Nel, in partnership with CSIRO, Australian Synchrotron and the School of Physics, has developed a combined methodology based on particle induced x-ray emission (PIXE), Australian Synchrotron powder diffraction (AS-PD) and microscopy to explore the ability of a complementary data set to analyse and identify ochres from various sources.

The research area ‘Assessing dimensional instability in cultural material: impact and responses to diverse climatic conditions’ has developed a radio frequency smart sensor platform for the non-invasive, in-situ investigation of cultural heritage to inform the dose-response functions of cultural materials in outdoor climates.

In the research area ‘Examining deterioration mechanisms in mould affected material’ Dr Nicole Tse has used laser speckle sensors to monitor biofilm activity from paper and paintings in simulated tropical environments with PhD student Caroline Kyi.

MMI, through the Materials Conservation Theme, is a sponsor of ICOM-CC 17th Triennial Conference, which will bring more than 800 conservators, conservation scientists and others to Melbourne from 15 – 17 September 2014.
Materials for energy 2013-2014 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.

The Materials for Energy Theme has focused on the high performance materials solar energy conversion, catalysis and solar concentration. With grant funding of over five million dollars, the theme supports eighteen postdoctoral fellows and ten masters/PhD students. Key areas of research have focused on organic semiconductors for large scale printed organic solar cells, engineered inorganic materials for future energy technologies and nanoparticle and quantum dots for solar cells.

The University of Melbourne, as part of the Victorian Organic Solar Cell Consortium (VicOSC), has delivered a number of new classes of organic semiconductors for flexible organic solar cells. The current very best performance for a p-type polymer, developed at the University of Melbourne, stands at 10.3% power conversion efficiency (PCE) - among the world’s best - and is only the second of two reported BHJ single junction devices with a reported efficiency of over 10% PCE. A stringent stage-gated selection process based on chemical, spectroscopic, physical and device properties allowed rapid development of the highest performance materials from over eighty new materials.

The technology has been transferred, using commercial printers, to a continuous process where A4 sized organic solar cell modules have been printed.

Light can be concentrated in large panes of glass by directing light to the glass edge for collection. New high performance organic materials have been designed to increase concentration efficiency and spectral range. Such materials have been synthesised and tested.

Development of template mesoporous, nanostructures inorganic oxides as scaffolds for high performance dye sensitised solar cells (DSSC) has been translated to large-scale for large scale printing trials.

New inorganic CdTe nanoparticle formulations have been developed for solution processed inorganic solar cells, and metal nanoparticles have been developed for a solid-state plasmonic solar cell using nanoparticle self assembly.
Materials for medicine 2013-2014 highlights

Theme leader
Prof Frank Caruso

Researchers
Prof Frank Caruso, Prof Stephen Kent, Prof James McCluskey, Prof Greg Qiao, Prof Robert Shepherd, A/Prof Andrea O’Connor, Dr Kwun Lun Cho, Dr Jiwei Cui, Dr Hirotaka Ejima, Dr Kristian Kempe, Dr Markus Müllner, Dr Rob de Rose, Dr Yan Yan, 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.

Novel responsive materials
The Nanostructured Interfaces and Materials Science (NIMS) group led by Prof Caruso has developed a new strategy to coat microscopic materials using polyphenols, leading to a new-generation particle system with engineered properties. The capsules can be engineered to degrade under different conditions, providing opportunities for the timed release of substances contained inside the capsules, and can be assembled rapidly from naturally occurring materials (minerals and nutrients) with specific physical and chemical properties, making it a versatile platform for various applications. This research has been published in Science in 2014 and received international attention.

Nanosensors for biology
The targeted delivery of nanoparticles requires an understanding of the biological processes involved in internalisation and intracellular trafficking. Prof Caruso’s team has developed a number of fluorescence-based molecular sensors to probe the environment inside cells during processing of nanoparticles, and internalisation of a capsule sensor.

Nano–bio interactions
Understanding the complex behaviour of the immune system in mediating immunity is crucial to designing effective nanoparticles for delivery of therapeutics. To tackle this, several groups under the nanomedicine theme have worked closely together. Profs Kent, McCluskey and Caruso and their teams have explored a set of immune–materials interactions. The teams have used a wide variety of techniques, such as proteomics, super-resolution microscopy and cutting-edge flow cytometry. The results of this research will have outcomes for the design and targeting of nanoparticles for vaccine delivery.
Materials processing 2013-2014 highlights

Theme leader
Prof Peter Scales and Prof George Franks

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 Anthony Stickland, Dr. Carolina Tallon, Dr Tuan Ngo.

Associated research centres
Cooperative Research Centre for Greenhouse Gas Technologies (CRCCO2), ARC Special Research Centre for Particulate Fluids Processing, Defence Materials Technology Centre, Australia-China Joint Research Centre on River Basin Management.

Particle flow manipulation
Many of the highlights in the past year in the materials processing arena relate to the manipulation of the flow of particulate materials to provide new products or in the manipulation of the meso and macro-scale structure of materials. The move from nano scale particle manufacture and manipulation to an understanding of the processing required to incorporate these particles into products is seen as the critical next step in particulate materials processing. It often requires the production of meso and macro-scale embodiments of the nano-particle system. Working out how to control aggregated structures and maintain the nano-particle attributes through processing is the focus of many current studies. This can include both particulate filled and metal composite materials. Bio-mimicry is useful but the processing step is rarely related.

Examples include the work of Franks and Ngo on infiltration of shear thickening (particle filled) fluids into Kevlar textiles in order to develop personal protective systems more resistant to stabbing threats and the work of Franks and Tallon on the development of multi-scale porous ceramics for potential applications in battery electrodes and ultra high temperature insulation for aerospace.

On the metal alloy and metal composites front, Kenong Xia has improved our understanding of the role of processing on the properties of Nickel Aluminium Bronze, providing alloys with improved strength and ductility and the work of Scales and others has highlighted the importance of particle dispersion in the growth of particle systems (see schematic on this page).

Left: Proposed growth mechanism of metal (Ag) nano-particles under concentrated conditions. Initially, nucleation occurs resulting in the formation of primary particles, of approximate size 0.6nm, shown at stage (A). Aggregation then occurs along high energy surfaces (B) with dissolution of grain boundaries to produce a particle with a coherent crystal structure (C). In the absence of a suitable particle stabiliser, secondary particles are then formed through aggregation (D) to produce particles with a non-coherent crystal structure (E). These particles still have the appearance of discrete particles, but take on a polygonal shape due to the presence of discernable twinned planes, shown at stage (F).
Quantum and nanophotonic materials 2013-2014 highlights

Theme leader
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 Tim Davis, 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, Dr Jiao Lin.

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.

Cybernetic diamond for targeted neuronal growth
Diamond is known to be biocompatible and suitable for use in neural applications acting as the material of choice for the current Bionic Eye Project, high acuity electrode. A team of researchers from the School of Physics and the Department of Anatomy and Neuroscience have fabricated a patterned substrate in diamond in which the vertical step height between conducting and insulating features was less than 3nm. In-vitro culture demonstrated that using this fabrication technique had no adverse effect on neural activity.

Nanodiamonds and silk
For the first time a group led by Dr Snjezana Tomljenovic-Hanc at the University of Melbourne, in collaboration with Tufts University, Medford and the University of Sydney, have combined two remarkable biocompatible materials – nanodiamonds and silk. This new hybrid material simultaneously meets all the requirements of biocompatibility, room temperature operation, and robust optical collection. This research, published in Biomedical Optics Express 5, 596 (2014), has attracted international attention, reaching a potential audience of at least 2.6 million people, and was highlighted by OSA News in January 2014.

Quantum decoherence detection
In recent years the convergence of nanotechnology and biology has produced some spectacular new perspectives of life at the nanoscale. A team consisting of researchers from the School of Physics, Department of Chemical and Biomolecular Engineering and the Department of Genetics has undertaken a significant step forward in the application of nanodiamond in in-vivo systems by demonstrating real time single particle tracking of these probes in the powerful genetic model system Drosophila Melanogaster. The first images of individual nanodiamonds in Drosophila embryos during embryogenesis were obtained and intracellular properties at the nanoscale probed. This groundbreaking demonstration was recently published in Biomedical Optics Express 5, 1250 (2014).

Fluorescent optical microscopy of immunostained neuronal cells on ultrananocrystalline diamond with polycrystalline diamond patterns. Neurons mostly survived on PCD. Scale bar: 100μm
**Interdisciplinary Seed Funding scheme**

**Scheme**

2012-13 was the last year that the Interdisciplinary Seed Funding Scheme was run by the Office of the Deputy Vice-Chancellor (Research). From 2013-14 the Scheme was run independently by most of the Institutes, including the MMI.

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.

In 2013-14 the MMI increased the scope of the selection criteria to include projects that had significant potential for industry or other external collaboration and funding.

**Selection process**

A sub-committee of the MMI Management Committee assessed the applications and ranked them according to the selection criteria.

The 2012-13 selection committee:  
- George Franks
- Daniel Gomez
- David Jones
- Andrea O’Connor
- Richard O’Hair

The 2013-14 selection committee:  
- Majorie Dunlop
- David Jones
- Andrea O’Connor
- Ann Roberts
- Peter Scales

- Damien Power
- Ann Roberts
- Anthony Stickland
- Annie Yan
- Steven Prawer

- Nicole Tse
- Yan (Annie) Yan
- Ray Dagastine
- Steven Prawer

**2013 & 2014 funded projects**

In 2013 $330,000 in funding was provided to 10 projects.

1. Multi-scale porous titanium diboride materials for battery cathodes
2. From pariah to messiah: using the mast cell to deliver nanoparticle-derived bioactive molecules
3. Nanoscale Pixel CMOS sensor
4. * Characterisation of nitinol for fabrication of intravascular stent electrode for novel brain-machine interface
5. * Cybernetic diamond for targeted neuronal growth
6. * High performance composite textile using shear thickening fluid
7. * A novel neuroscience-inspired many-state logic element for artificial brain tissue replication and low power, massively parallel information processing, sensing and control
8. * Structure and function dynamics in remodelling of airway smooth muscle (ASM) cells through quantitative imaging
9. * Multiple sensors for the in situ, non-invasive investigation of works of art
10. * Quantum levitation and confined diffusion of colloidal particles

Final reports from these projects are presented on the following pages.

In 2014 $220,000 in funding was provided to 8 projects.

1. * Fullerene molecular peapods as organic semiconductors - Wallace Wong
2. * Tissue engineering fish meat: biofabrication strategies to address declining global fish stocks - Andrea O’Connor
3. * Graphene thin films with tailored nano-architectures: a new class of antibacterial coating - Michelle Gee
4. * A miniaturised, ultra-high sensitivity electronic detection platform for magnetic immunosassays - Simone Gambini
5. * Photovoltaic energy delivery system for implantable microelectronic medical prostheses - Arman Ahnood
8. * Nanocrystals for Upconversion Laser Chips - Tich-Lam Nguyen

*MMI-funded projects, others funded centrally.
Nanoscale Pixel CMOS Sensor

Investigators: Dr Ranjith Rajasekharan Unnithan, Dr Kumar Ganesan, Dr Timothy Karle, School of Physics; Prof Stan Skafidas, Dept of Electrical and Electronic Engineering.

Purpose
Pixel size limits the information that can be either recorded in a CMOS imaging sensor or displayed in a liquid crystal display. Hence the pixel size has a tremendous impact on all the applications involving the CMOS imaging sensors and the displays. However, down scaling of colour pixel size to the nanoscale using conventional colour filters is hindered by colour cross talk, diffraction and pixel boundary effects. This is because the conventional colour filters are made of dyes or pigments and exploit their particular absorption properties to produce different colours. Furthermore, RGB filters utilising existing technology must be fabricated in several steps which present challenges when trying to accomplish nanoscale alignment. Even if a technology using the pigments or dyes is developed for RGB nanometer colour pixel fabrication, the colour cross talk will make them unsuitable for practical applications. Coupling light into nanoscale pixels is also extremely difficult due to diffraction. These issues call for new strategies for the fabrication of nanometer sized colour pixels. Our proposal is about the development of nanometer size plasmonic RGB colour pixels by addressing difficulties at nanoscale. The proposed pixel technology has tremendous impact on all the applications involving the CMOS imaging sensors (e.g. CMOS based endoscopes, robotic eye, lab-on-chip sensors and mobile phones), high resolution liquid crystal displays and RGB spatial light modulators.

Progress
We have developed a prototype nanometer plasmonic colour pixel by addressing pixel stitching errors at nanoscale by combining surface plasmon and Fabry-Perot resonances. Our study started with finding the minimum pixel size achievable using simple holes in Aluminium. The results showed that the minimum number of holes required for realizing a nanometer colour pixel is three in a triangular arrangement. The pixel thus defined is polarization independent due to its symmetry. Based on these results, we first developed nanoscale RGB pixels using simple holes by tuning the surface plasmon resonances to demonstrate the pixel stitching errors at nanoscale and angle sensitivity. We then fabricated a coaxial hole geometry in Aluminium to produce angle insensitive pixels, exploiting Fabry-Perot resonances. We also showed that the nanometer pixels exhibited pixel stitching errors at the boundaries. The stitching errors cause blur, reduced sharpness and discontinuities in the displayed images. In order to eliminate the stitching errors, we developed simple but powerful filling strategies at nanoscale by combining surface plasmon and Fabry-Perot resonances. We demonstrated that it is possible to overcome stitching errors at the pixel boundaries and to produce nanoscale pixels, which are polarization independent, angle insensitive and based on CMOS compatible aluminium technology. The project is still running as the MRO has extended our project until 1st June 2014. A final report will be ready in the end of June.

Plasmonic colour pixels fabricated using finite number of holes in aluminium (a) SEM image of three letters - MMI (b) Magnified SEM image (c) Corresponding optical image shows red, green and blue (RGB) colour from each letter. Different pitch and hole diameter was used for getting different colours.
Characterisation of Nitinol for Fabrication of Intravascular Stent Electrode for Novel Brain-Machine Interface

Investigators: Dr Nick Opie, Dr Thomas Oxley, Prof Terence O’Brien, Dept of Medicine; Prof Anthony Burkitt, A/Prof David Grayden, Dept of Electrical and Electronic Engineering; Prof Steven Prawer, Dr David Garrett, Dr Kate Fox, School of Physics.

Purpose

Brain machine interfaces aim to enable paralysed and amputated people to regain motor function using thoughts alone. By implanting an electrode array on or near the brain, neural signals can be extracted and used to control a prosthetic limb or computer. Current technology requires invasive brain surgery and carries a high risk of complication. A brain machine interface that can be implanted using minimally invasive techniques is currently under development by our team, and we have evaluated the potential of using a self-expanding Nitinol stent to assist with device insertion.

Evaluation of electrochemical properties and bioactivity of Nitinol was conducted to identify the feasibility of this material for use as a brain machine interface platform. We have shown, that while Nitinol is not suitable for effective stimulation of neural tissue, recording brain activity may be possible. Further, we have determined the bioactivity of Nitinol and compared it to common implantable biomaterials.

Based on this research, we have begun developing application specific Nitinol stents which will significantly enhance development our device as we strive for human clinical trials.

Progress

The primary aim of this project was to determine the electrochemical and biological properties of Nitinol, and its potential application for use in a brain machine interface. We manufactured Nitinol electrodes and compared them to Platinum electrodes using impedance spectroscopy and cyclic voltammetry.

While Nitinol was not observed to be suitable as a stimulating electrode, the potential of this material for use as a recording electrode may be possible. Further research will be conducted to evaluate the potential of a Nitinol electrode (compared to common stainless steel and platinum) to record neural information in an awake and freely moving animal cohort. This will be conducted early in 2014. Further, we have shown Nitinol as a suitable material for implantation, comparing the bioreactivity of Nitinol to platinum and titanium.

Preliminary work has also been undertaken to design and manufacture application specific Nitinol stents, in collaboration with Jeff Rank from The Laser Experts Inc. This research will significantly enhance the development and potential of our device enabling us to mount sophisticated electrical components and circuitry on the implantable device.
Cybernetic diamond for targeted neuronal growth

Investigators: Dr Kate Fox, School of Physics; Dr Kimberly Christie, Dept of Anatomy ad Neurosciecne

Purpose

Many different materials have been used to directly interface with neural cell populations. However, due to the inherent properties of most biocompatible materials, direct interfacing has proven to be challenging. As a result, most materials require an intermediate biological adhesion layer, usually poly-ornathine or poly-D-lysine. By adding this secondary coating, the biomaterial thus risks delamination and a potentially compromised interface. Accordingly, the aim of the project was to investigate whether a diamond substrate could effectively serve as an interface material for neural integration. Diamond is known to be biocompatible and suitable for use in neural applications acting as the material of choice for the current Bionic Eye Project high acuity electrode. However, it remains unknown whether diamond under electrical stimulation can serve as an interface material that not only enables a close alignment of the material with the neural population but also can be used to target neural growth and directionality under an electrical stimulus.

Progress

Significant work has been undertaken to establish the best method for fabricating the diamond substrates to ensure that neural interfacing is best achieved. Using primary neurons, a study was done to first establish whether neuronal cell adhesion had a preference for conductive diamond. Neuronal cell adhesion was assessed on our preferred substrate, nitrogen-incorporated ultrananocystalline diamond (N-UNCD, conductive) but also on UNCD (insulating), polycrystalline diamond (PCD, insulating) and a control, tissue culture plastic (insulating). After 24 hours, neuronal cells were healthy with strong neurite formation on all samples. However, specifically assessing neurite outgrowth and density, a clear preference was seen towards the N-UNCD samples compared to other samples (p<0.0001).

Based on the clear selectivity of the neurons to the conductive features compared to insulating features a patterned substrate was fabricated. In order to remove topographical features from the assessment of neural selectivity, substrates were fabricated using reactive ion etching of diamond on a sacrificial silicon substrate. By doing so, we fabricated a patterned substrate in which the step between conducting and insulating features was less than 3nm. A second in vitro culture was performed to assess whether this fabrication technique had any effect on neural activity. Here, the surface roughness of both N-UNCD and UNCD was assessed for its impact on the cellular activity. It was found that neuron density was significantly better on the conductive N-UNCD compared to the UNCD, irrespective of average surface roughness. Interestingly, however, in a bacterial assay, the smooth N-UNCD showed antibacterial properties compared to the rough N-UNCD. This gives us confidence that the patterned substrate fabricated through RIE will be a good neural interface.

The next phase of the project is to now test the patterned N-UNCD:UNCD substrates in a neural culture and a bacterial assay to determine whether there is an inherent preference to cell seeding and adherence. After this, we expect to begin to apply a current to the substrate to begin to assess whether we can elicit specific growth and neurite outgrowth conditions. This is expected to occur in the first half of 2014.

Above: Confocal microscope image of rat cortical neurons on diamond exhibiting neurite outgrowth. Below: Patterned smooth diamond substrate showing an array of conducting N-UNCD pads surrounded by insulating UNCD. Credit W. Tong
High Performance Composite Textile Using Shear Thickening Fluid

Investigators: Dr Tuan Ngo, Dr Phuong Tran, Prof Priyan Mendis, Dept of Infrastructure Engineering; A/Prof Ray Dagastine, Dept of Chemical and Biomolecular Engineering; Dr Bill Humphries, Advanced Fibrous Materials, CSIRO.

Purpose
Significant efforts have been devoted to improving the ballistic and piercing resistance of composites by either enhancing the energy dissipation or preventing projectile penetration. Efficiently combining both capabilities into a single composite structure is still a huge challenge. Other factors including cost, weight, thermal-mechanical reliability and flexibility also need to be considered. A particular example is body armour, which is essential in protecting police and military personnel from wide range of risks. Other examples include innovative medical gloves, protecting medical practitioners from potential needle piercing, or, manufacturing of structurally reinforced panels, which protect miners from rock impacts in accidental mine collapses.

The key aim of this project is to develop an advanced composite structure based on the integration of multi-layer fabrics woven/knitted from high performance fibres (Kevlar, Twaron & Dyneema) and a shear thickening fluid (STF). STFs exhibit a reversible fluid-to-solid phase transformation when subjected to high strain rate impact. Shear thickening results when a colloidal suspension of solid particles dispersed in a liquid medium very close to the maximum packing become “jammed” when sheared at high rate switching behaviour form liquid-like to solid-like. Shear thickening fluids can be saturated into fabrics in order to create a flexible garment which stiffens upon high strain rate such as the impact of a sharp projectile.

The multi-layer fabrics will be designed to give the overall structural integrity to the composite structure against impact loadings, while STFs provide the mechanism to stiffen and harden the cloth. This project will also focus on developing methodology to incorporate STFs into the composite structures including fabric impregnation and encapsulation process. This innovative research project will significantly enhance the resistance of military and civil armour protecting humans and structures from extreme impact.

Progress
We have successfully suspended the micro-particles in the solvent achieving the shear thickening effect and produced several mixes of STF. We have also developed a drop tower for testing fabrics subjected to impact. The fabrics were saturated with developed mixtures and were subjected to a stab resistance test in compliance with NIJ Standard–0115.00. Using the drop tower test, the increased piercing resistance of STF embedded fabrics successfully demonstrated. STF embedded fabrics showed substantial increased resistance to piercing attack where control samples were subject to severe tearing.

![Numerical modelling and impact testing of STF embedded multilayer fabric](a)
![Mesoscale modelling of woven fabric subjected to piercing impact](b)
![Schematic of thickening mechanism and ballistic resistance of STF-embedded multilayer fabric](c)
![Experimental results on piercing impact resistance of saturated fabric](d)

(a) Numerical modelling and impact testing of STF embedded multilayer fabric. (b) Mesoscale modelling of woven fabric subjected to piercing impact to validate the experiments performed by using drop tower setup. Schematic of thickening mechanism and ballistic resistance of STF-embedded multilayer fabric. Experimental results on piercing impact resistance of saturated fabric with top view (e) and bottom view (d) demonstrated the stab resistance capability of the STF-embedded multilayer fabric over those without STF in the control test (f). Credit: T. Ngo, P. Tran, E. Yang.
A novel neuroscience-inspired many-state logic element for artificial brain tissue replication and low power, massively parallel information processing, sensing and control

Investigators: Dr Colin Hales, A/Prof David Grayden, Electrical and Electronic Engineering; Dr Kumar Ganesan, School of Physics; Peter Kitchener, Dept of Anatomy and Neuroscience.

Purpose

This project aims to examine the fundamental properties of a novel processing element for a new kind of neuromorphic chip aimed at, ultimately, artificial (inorganic) brain tissue. It targets inorganic replication of the fundamental electromagnetism common to all brain cellular operations. This means that the device expresses (1) action potential coupling and (2) purely electromagnetic coupling. These are the two signalling mechanisms known to exist in the brain.

Based on the exploration we will have the basis for a fundamental processing element for an eventual large-scale integrated chip. The plan was to do the basic science to characterise the device's properties for single units, pairs and small arrays of the devices. Based on the knowledge gained, a subsequent much larger project will look at the nanofabrication needed for the first bits of real artificial ‘brain tissue’.

Progress

Progressing this project has proven to be very challenging for purely logistical reasons. Firstly, and even as this is being written, continuing attempts to do a computational examination of the device design using COMSOL have failed due to numerical solver instability. It is possible that the particular unusual non-homogeneous, time-varying collection of material conductivities and permittivities, needed to exhibit the properties being utilised, renders Maxwell’s equations into a form ill suited to the techniques of mainstream numerical solver technology. This is unclear and more work needs to be done.

Secondly, it turned out all fabrication had to be done by project member Colin Hales. This meant a large learning curve that did not become apparent until Sept 2013. The exploratory fabrication needed to create a working device is still in its early stages. Images show the components of a single basic device: a circular planar capacitor discharged by leads that access the device from the same side of the body of the device.

Dr Peter Kitchener has provided lab space in the medical building where preliminary non-cleanroom fabrication processes have been going on. Since Jan 2014, months of problematic COMSOL simulations have continued to thwart refinement of the design.

Undaunted by the logistical difficulties, this team will outlast the official funding period and continue on until the device is characterised, fabricated and tested. The plan to have a large ARC discovery grant to progress the device to the next stage in its evolution to fully functional artificial brain tissue in neuromorphic chip form.

Top at left: Laser drilled prototype diamond substrate (capacitor dielectric) prior to plating. Bottom at left: Prototype leadwire assembly prior to tip plating. Credit: C. Hales.
Structure and function dynamics in remodeling of airway smooth muscle (ASM) cells through quantitative imaging

Investigators: Dr Shan Shan Kou, Prof Ann Roberts, A/Prof Harry Quiney, School of Physics; Prof Alastair Stewart, Dept of Pharmacology; Prof Lea Delbridge, Dept of Physiology; A/Prof Peter Lee, Dept of Mechanical Engineering.

**Purpose**

We aim to develop a label-free, high-throughput functional imaging modality to provide insights into pathogenesis of asthma and chronic obstructive pulmonary diseases (COPD). We will relate the underlying protein content (phase sensitive) and the orientations of actin filaments (polarization sensitive) to the computed quantitative label-free images. In expansion, we would also like to explore different ways of probing the cells with tailored waves to achieve the final goal of inferring functional meaning from changes in cellular structures through optical interpretations quantitatively.

**Progress**

The first 6 months of the project involved considerable planning and equipment purchasing. We are building a microscope prototype that is sensitive to both optical phase and polarization information. First we have successfully implemented a custom-made bench-top imaging microscope. Currently several opto-electronics devices are being embedded into the optical setup for customary control of the light propagation and polarization. Algorithms for quantitative phase have been successfully applied to macrophage cells. Currently we are adapting these algorithms to the newly built system. For light propagation and beam control, we are exploring an alternative mode using surface waves as a probe rather than free-space light. This will allow visualization of cellular membrane changes at superior resolutions, often of interest during the cellular remodeling process as well. Some possibilities of manipulation of surface waves through designed nanostructures have been considered.

Finally for feasible biomedical studies, a bio-compatible viewing chamber was purchased and is planned to be incorporated into the multi-modal system. This will allow us the ultimate goal of observing live cellular morphological and structural information to explore the underlining biological functions.

Two publications resulted from the seed grant. Two summer students were trained in the project (Michael Malek and Robert De Gille).

Differential Interference Contrast (DIC) image of macrophage cells (top). Computed phase image of the same cells (bottom). Credit: Robert De Gille
Multiple sensors for the in situ, non-invasive investigation of works of art

Investigators: Dr Nicole Tse, Caroline Kyi, Centre of Cultural Materials Conservation; Prof Carl Schiesser, School of Chemistry; Prof Ann Roberts, School of Physics; A/Prof Peter Farrell, Dept of Electronic and Electrical Engineering; Dr Graham Brodie, Dept of Agriculture and Food Systems.

Purpose
The development of ‘damage functions’ for Australia’s diverse range of works of art composed of a wide variety of materials is important for research-led conservation practice and the future of collections. Materials conservation aims to achieve this with non-invasive, in-situ investigatory tools, however no single technique is currently able to meet this demand. The aim of this project was to evaluate and develop an innovative multiple sensor for the non-invasive, in-situ investigation of cultural materials. We showed that Dynamic Speckle Analysis (DSA) can monitor the temporal ‘activity’ of acrylic paints, paper-based items, metal corrosion and canvas paintings aged in varying environments. This was achieved by developing a portable DSA unit integrated with pressure, temperature, light and relative humidity readings with a user friendly computer interface. A radio frequency (RF) sensor has been used to successfully detect the invasion of wood by termites and fungus-driven deterioration of wood by measuring activity below the surface of an object at varying depths. We extended this technique to investigate works of art and outdoor wooden sculptures. Thus our aim was to exploit laser speckle and radio frequencies to monitor activity on and below the surface of significant cultural materials with integrated sensors with multiple diagnostic abilities.

Progress
This project developed a smart sensor platform for the non-invasive, in-situ investigation of cultural heritage to inform the dose-response functions of cultural materials in diverse climates. This research informed the preservation of collections in non-standard museum climates as located in the tropical regions of Australia and Southeast Asia. Outcomes included 2 peer reviewed papers, one proposed ARC Linkage application for 2015, the development of a consortium to address this issue, the supervision of two Minor Theses students, and use of the non-invasive sensors in teaching.

Research in 2013 focused on three main aspects: the DSA unit was used to monitor activity associated with mould growth on paper in controlled conditions and to investigate the development of corrosion on metal samples. The RF unit was developed and used to investigate water transport through an outdoor wooden sculpture. Climatically controlled rooms were used to enable the growth of model cultures of *Aspergillus niger* that are common in works of art. The portable DSA unit was used to monitor the surface activity of these samples, and correlated with cell count research in Free Radical Chemistry. Activity of corrosion crusts on copper and copper alloys was investigated using the portable DSA unit. The unit was shown to recognise surface changes associated with corrosion and give an indication of the rate, although further changes to make the technique useful in a museum setting. Experiments were conducted on an outdoor wooden sculpture to monitor the changing moisture content caused by external events using the RF unit. Results showed that moisture uptake by the sculpture could be seen after a precipitation event, demonstrating the sensor’s use in-situ.

RF analysis of water transport in outdoor wooden sculpture: a) Bruce Armstrong, 1986, She would like to be left with it, Collection of Ian Potter Museum of Art University of Melbourne, 1986.0182; b) in-situ set up of equipment showing crossed and parallel antennae. Credit E. Harris. c) RF ‘Look Through’ system. Propagation of microwave radiation through open space compared to propagation through wood. Credit G. Brodie.
Quantum levitation and confined diffusion of colloidal particles

Investigators: A/Prof Ray Dagastine, Dept of Chemical and Biomolecular Engineering; Prof Franz Grieser, School of Chemistry.

Purpose
Nanoscale geometric confinement of molecules, polymers and particles can mediate the diffusion and transport properties of these systems compared to their bulk behaviors. Understanding these effects is crucial in predicting transport process behavior through a wide range of materials including ion channels in cell membranes, concentrated particle suspensions in micro-fluidic channels, and porous media used in adsorption and filtration processes such as water treatment and gas separations. Both existing experiments and models have predicted that confinement effects significantly differ from normal Fickian diffusion. The goal of this work is to study confinement effect of micron sized particles levitated under Brownain motion is a fast a reliable measure the of the individual particle radius. Methods including Total Internal Reflection Microscopy (TIRM) can weigh individual particle with femto-Newton resolution, but this can take up to an hour per particle and may be hindered by the micro-channels that the particles are confined in. To solve this problem we have developed a new method to size these micron-sized particles. In this work we have used a scattering hotspot at the edge of a particle in generated in a TIRM measurement and the centre of the particle determined by using common bright field microscopy to size the particle. By comparing results against a standard radiation pressure method for measuring particle radius during a TIRM experiment, we have shown this method is valid for a range of particle sizes and materials. This frustrated evanescent wave particle sizing (FEWPS) technique has also been implemented in a semi-automated way to generate size distributions for polystyrene and silica microspheres ranging in size from 1-10μm, finding excellent agreement with NIST-certified distributions across a range of statistical measures.

Progress
One of the key first steps in the study of the confinement of micron size particles levitated under Brownian motion is a fast a reliable measure the of the individual particle radius. Methods including Total Internal Reflection Microscopy (TIRM) can weigh individual particle with femto-Newton resolution, but this can take up to an hour per particle and may be hindered by the micro-channels that the particles are confined in. To solve this problem we have developed a new method to size these micron-sized particles. In this work we have used a scattering hotspot at the edge of a particle in generated in a TIRM measurement and the centre of the particle determined by using common bright field microscopy to size the particle. By comparing results against a standard radiation pressure method for measuring particle radius during a TIRM experiment, we have shown this method is valid for a range of particle sizes and materials. This frustrated evanescent wave particle sizing (FEWPS) technique has also been implemented in a semi-automated way to generate size distributions for polystyrene and silica microspheres ranging in size from 1-10μm, finding excellent agreement with NIST-certified distributions across a range of statistical measures.

A dark field image of the scattering hot spot of a particle frustrating an evanescent wave in a Total Internal Reflection Microscopy measurement. Credit: Christopher G. Bolton.
Multi-Scale Porous Titanium Diboride (TiB$_2$) Materials For Battery Cathodes

**Purpose**

Electrochemical cells are fundamental to a large number of applications, from large scale engineering classical processes, as the smelting of alumina into aluminium in the Hall-Heroult cell, to possible everyday innovative concepts, such as the fabrication metal-air batteries as a rechargeable energy source.

Regardless of the type of electrochemical process involved, cathode reactions are responsible for the production of electrons in the cell. In general, cathode materials must be able to withstand high temperature, corrosive environments while showing sufficient mechanical strength and electrical conductivity. Therefore the efficiency and success of the electrochemical cell relies on the correct material selection for the cathode.

Materials evaluations for the Hall-Heroult cathode, one of the most extreme and corrosive environments for materials, have shown that the ceramic material Titanium Diboride (TiB$_2$) is a suitable option for cathodes due to its superb chemical inertness and its good electrical conductivity. But finding the suitable material is just the beginning. The material has to have the right microstructure. While Hall-Heroult cathodes must be fully dense materials, their counterparts for lithium-air batteries must be porous, to guarantee the air supply for the reaction at the cathode. The reaction product of the cathode reaction should be insoluble, and needs to stay "stored" around the pores orifices without blocking the passage for air which could discontinue the energy production.

Our project is focused on the development of a multi-scale porous TiB$_2$ to be evaluated as a candidate material for cathodes in lithium-air batteries. The use of ceramic colloidal processing techniques allows for tailoring and design of the porous microstructure. Thus the effect of the different processing schemes on pore size, permeability, diffusivity, mechanical strength and electrical conductivity will be studied. In addition, the shape of the pores and the distribution of the porosity will be also evaluated as a tool to minimize pore blockage by the cathode reaction products.

**Progress**

Colloidal processing techniques have been successfully applied for the preparation of multi-scale porous TiB$_2$ materials for cathode applications. Four types of single-scale porosity materials have been produced by particle stabilized foams, replica, freeze casting and partial sintering. The type of porosity ranges from closed-bubble-like to open-interconnected pores. Tailoring the processing conditions allows the preparation of highly porous materials (up to 92% porosity) with pore sizes in the range of 80-1000 μm. Different multi-scale materials have been produced and they will be characterized and evaluated for their application in cathodes for lithium air batteries.

![Scanning electron micrographs of porous Titanium Diboride (TiB$_2$) samples produced using various colloidal processing techniques. Clockwise from top left: Particle stabilized foams, freeze casting, partial sintering, replica. Credit: C. Tallon, G.V. Franks, R. Miller & H.C Kim.](image-url)
From Pariah to Messiah: Using the Mast Cell to Deliver Nanoparticle-Derived Bioactive Molecules

Investigators: Dr Graham Mackay, Dept of Pharmacology and Therapeutics/Medicine; Dr Anton Blencowe, Dept of Chemical and Biomolecular Engineering; Prof Paul Gleeson, Dept of Biochemistry and Bio21.

Purpose
In the body, mast cells are best known for their deleterious role in producing the symptoms of allergic disease. Allergic symptoms are caused by mast cell ‘degranulation’ where cytoplasmic secretory vesicles (granules) exocytose releasing mediators such as histamine. This project aims to harness this process of mast cell degranulation as a novel drug delivery system.

Our strategy is to deliver drug payloads to mast cell granules using targeted nanoparticles. These nanoparticles are designed to decompose in the low pH environment of the granule. The drug payload is then released from the mast cell through degranulation. As a proof-of-concept system we have chosen to deliver the clinically utilised anti-histamine desloratidine. Thus, upon mast cell activation an anti-histamine would be immediately available to counter the undesirable actions of histamine.

Successful targeting of drugs to mast cells, and their selective release through degranulation, will open up new drug delivery opportunities not just for allergic disease, but potentially for many other disorders where drug therapy is as yet sub-optimal.

Progress
Acetylated dextran/desloratadine nanoparticles (Ac-Dex/Des NPs), and matched particles that lacked desloratidine incorporation (Ac-Dex), were synthesised via oil-in-water nano-emulsion. The particles were shown to be relatively homogeneous with mean particle size of 100 nm as measured by scanning electron microscopy and dynamic light scattering. The particles, even at concentrations of 100 μg/ml, had negligible effects on the viability of two mast cell lines (HMC-1 and LAD2) nor did they directly activate mast cell degranulation or cytokine release. These properties mean that the NPs are suitable for analysis of their uptake, trafficking and disassembly in mast cells.

Fluorescently labelled NPs were shown to be taken up mast cells but assessment of trafficking of these particles was hindered by loss of the fluorophore from the NPs. Likewise, free desloratidine emerging from the NPs, which is known to directly inhibit mast cell activation, confounded the interpretation of a novel bioassay of histamine activity which measures histamine-induced Ca\(^{2+}\) flux in the fibroblast cell line SW982. Second-generation NPs are currently being synthesised with covalently incorporated fluorophore and more stably integrated desloratidine. These reagents will greatly facilitate our ongoing work in 2014 to determine if the mast cell can indeed be used as a novel drug delivery system.

Scanning electron microscopy images of acetylated dextran/desloratadine nanoparticles (a,b). Credit: Blencowe, Cho and Halim, Chemical & Biomolecular Engineering, the University of Melbourne.
MCN Access Scheme

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 through the training of 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 invites 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 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

So far five merit-based applications have been approved, which include projects for the fabrication of polymer solar cells, devices for the investigation of cell biomechanics, fabrication of neuro-inspired nanoelectronic devices, and fabrication of devices with submicron pixels using plasmonic filters.
Platform Development Pilot Program

2013 has been an exciting year for the Platform Development Pilot Program (PDPP) with the commencement of a third pilot platform, a doubling in users and instrument use across all of the platforms and a positive future beyond the pilot program.

Background of the PDPP

In August 2012, the MMI, in collaboration with the Melbourne School of Engineering and Melbourne Research Infrastructure and Strategy, founded the platform development pilot program, with the commencement of 3 platforms:

- Nanomaterials Characterisation (NMC)
- Advanced Fluorescence Imaging (AFI)
- Nanofabrication (NF)

The nanomaterials characterisation (NMC) and advanced fluorescence imaging (AFI) platform formally commenced in August 2012, with the employment of two platform support officers (PSO): Marta Redrado Notivoli (NMC) and Ben Hibbs (AFI). The third platform, nanofabrication (NF), would see the PSO seconded to the MCN on a full-time basis. Dan Smith commenced his role of the nanofabrication platform support officer in May 2013. In September 2013 a new Platform Support Coordinator, Dr Lauren Hyde, was employed to manage the three platforms and help promote the capabilities to internal and external researchers and industry.

The intention of the MMI pilot platform was to support a critical mass in materials research infrastructure in terms of equipment and technical support on an easily accessible basis for a much larger research community not limited by the boundaries of individual groups. The goals of the MMI program also aligns with the future directions for a University-wide system of support designed to support as many research groups as possible with a limited set of infrastructure resources.

Platform User Survey

In January 2014, a User Survey was conducted with platform users, seeking feedback regarding many topics relating to the platform including communication, training procedures, data transfer, publications, as well as improvements and a ‘wish list’ for future capabilities.

There was an overwhelmingly positive response from users across all three platforms, with a >90% approval rating for the overall experience of the platform. Training procedures and communication between PSOs and users were particularly impressive, as was the fact that most users planned on using the platform again and would recommend the Platforms to their colleagues.

The constructive feedback we have received will enable us to further improve our users experience including the development of a more detailed website, and regular updates to our users. Additionally, the ‘wish list’ of new capabilities highlighted by users will be valuable when considering platform expansion and future LIEF applications.

The Cypher AFM, the world’s highest resolution AFM. Credit: Marta Redrado.
Platform Development Pilot Program

Nanomaterials Characterisation
Platform Support Officer: Marta Redrado Notivoli
Academic Leader: A/Prof Raymond Dagastine

Capabilities
The nano-materials characterisation (NMC) platform can be used to characterise the nano- and micro-scale properties of a diverse range of samples including bulk materials, thin films, nanoparticles and even living cells and tissues. Our platform is currently the leading scanning probe microscopy facility in Australia. With a particular specialty on Atomic Force Microscopy (AFM) and nano-indentation, a detailed analysis of material properties, forces and interactions at the nanoscale can be conducted.

Upgrades
The most recent upgrade of the facilities include a new tip holder that uses more than one drive frequency to the AFM cantilever to be able to probe variations in sample materials properties in real time without complicated post analysis processes. This type of method is reflective of the direction of AFM instrument development in the last several years. We also had some exiting outreach activities through tours as well as running a practical laboratory for geoscience around atomic visualisation of mineral surfaces. This period also saw a significant upgrade and recommissioning of the nano-/micro- indenter system. The nanoindenter is capable of investigating the mechanical properties of a wide range of materials including thin films, teeth, crystals, geopolymers and metals. Mechanical properties such as Young’s modulus as well as scratch, impact and fracture testing are possible. Additional capabilities including a liquid cell and a heated stage will become available in the second half of 2014.

Users
The NMC platform has doubled its user base since April 2013. Additionally more than half of the instruments on the platform have seen a doubling in the number of instrument hours, demonstrating the increasing value for this platform to UoM researchers.

Publications Enabled
In the first year of the platform we have seen some exciting outcomes in the area of AFM including users with high profile publications including Science, Cell and Journal of Physical Chemistry Letters from different research groups and across three faculties. Additionally, 18 journal articles have been published as a result of the use of the nanomaterials characterisation instrumentation.
Advanced Fluorescence Imaging
Platform Support Officer: Benjamin Hibbs
Academic Leader: Dr Yan Yan

Capabilities
The Advanced Fluorescence Imaging (AFI) platform provides super-resolution optical microscopy capabilities, allowing unparalleled insight into the structure of nanomaterials, sub-cellular organelles and tissues sections at the nanoscale. The instrumentation provides the ability to resolve objects down to ~20 nm in diameter inside cells, allowing unparalleled insight and understanding into nanomaterial-biological interactions. Whilst super-resolution microscopy is a powerful tool for visualising materials and sub-cellular structures, it may only tell part of the story. The platform also offers high-throughput instrumentation, such as imaging flow cytometry.

Progress
Over the past year, the AFI platform has contributed to a wide variety of research projects across the materials, biological and physical sciences. The OMX Structured Illumination Microscope, with its unparalleled combination of speed and sensitivity at a resolution down to 100 nm, has been used to image sub-150 nm particles inside cells, characterise the distribution of receptor protein aggregates on cancer cells and resolve the interaction of novel cell-penetrating polymers with bacteria. The recent addition of a third camera and a 642 nm laser has expanded the capabilities of the instrument to further complement the platform’s other instrumentation. In conjunction with the high sensitivity and high throughput of the Apogee μFlow Cytometer, the OMX has contributed to the characterisation of sub 100 nm bacterial vesicles in the aqueous state, research that is not possible by any other technique.

The Nikon N-STORM system, with the ability to resolve objects down to ~20 nm in diameter, complements the OMX system and has proven invaluable in determining the nanostructure of receptor protein clusters in cancer cells, as well as probing the internal nano-pore structure of hydrogels. The Amnis Imagestream Imaging Flow Cytometer has contributed to a variety of projects, utilising its unique high-throughput capabilities. The instrument was used to quantify protein clusters in dendritic cells, as well as studies of cellular internalisation of nanoparticles.

The flexibility of the powerful imaging and characterisation techniques available make the AFI platform a unique resource to the materials and biological sciences. The combination of instrumentation allows platform users to investigate cellular processes and materials in ways never seen before.

Users
The AFI platform has also seen a 100% increase in the number of new users since April 2013. Additionally, there has been significant uptake of all of the platform instrumentation, in particular the flagship instruments (OMX, STORM and imaging flow cytometer) with a doubling in the number of instrument hours for each of these instruments.

Publications Enabled
The AFI platform instrumentation has helped facilitate the publication of 23 journal articles, including high-profile publications in Science, Advanced Materials and Angewandte Chemie International Edition.
Platform Development Pilot Program

Nanofabrication
Platform Support Officer: Dan Smith
Academic Leader: A/Prof Raymond Dagastine

Introduction
The nanofabrication platform formally began in May 2013 with the commencement of our platform support officer, Dan Smith. The PSO is on secondment at the Melbourne Centre for Nanofabrication (MCN), and is based full-time at the MCN in Clayton, so as to assist UoM MCN users in a timely manner. The MCN houses the largest research fabrication cleanroom in Australia, with key capabilities in lithography, thin film deposition, etching, design & prototyping and characterisation.

Support and Services
The nanofabrication platform provides the following services for UoM researchers:

• First point of call for UoM researchers
• Experiment design and training plans
• Training on MCN equipment
• MCN access and safety inductions
• Process development and process flow creation
• Liaise with MCN instrument managers
• Platform officer’s time for training and technical support is free for UoM researchers
• Substantial discounts on MCN rates for UoM researchers through a block purchase scheme

Discounted Access
Since June 2012 the MMI has facilitated the purchase of a pre-paid block of MCN instrument time, whereby a 30% discount on standard instruments rates is applied. This MCN block account is available to all UoM researchers who wish to use the MCN, with researchers internally billed on a monthly basis to recover the purchase cost. This program has saved UoM researchers upwards of $21,000 so far. This scheme was viewed as a valuable initiative setup by the MMI, as indicated by the recent user survey.

Merit-Based Application
A merit-based access scheme was established in June 2012 to support UoM researchers new to the MCN with free access for a defined period of time to support prototyping and/or development of a new device. In 2013, 35 merit-based hours were awarded to UoM researchers, totaling $2,975 in free MCN access.

Publications Enabled
Additionally, 9 journal articles have been published by UoM researchers as a result of the use of the MCN capabilities.

Inside the MCN clean room, Credit: MCN
Outlook of the Platform Development Pilot Program

The Platform Development Pilot Program (PDPP) was to run for 2 years (until 31st August 2014) whereby it was envisaged that following demonstration for the supportive uptake of the platforms and demonstration of their value to enabling research at UoM, the platforms would transition into a permanent fixture at the UoM with financial support from both faculties and centrally.

The Pilot Program was successful. There has been a broadening and increase in the userbase, instrument up-time and an increase the profile of the platform.

We are very excited about the year ahead with several major initiatives coming into effect in 2014 including the transfer of the platform development pilot program into the Melbourne Research MCRIP initiative, addition of a new node to the platform, as well as several initiatives and seminars to improve the research experience for our users. These initiatives aim to make materials research more accessible to a larger research demographic, and providing the technical expertise and instrument support to help our users achieve their research goals.

A new website has been launched for the materials characterisation and fabrication platforms and can be found at http://nanomaterials.unimelb.edu.au

From August 2014, the Program will gain X-Ray Diffraction (XRD) analysis capability. Dr Matthew Rowles has recently been employed as the PSO for the XRD, with Prof George Franks as the academic leader. XRD provides information on the structure of your material. As the arrangement of the atoms in a material determines how a material behaves, the combination of structural and chemical analyses can provide further insights into materials.

The XRD node can provide a variety of services including:
- Crystalline phase identification
- Quantitative phase analysis
- Crystallite size determination
- Strain analysis
- Data interpretation and analysis

X-Ray Diffraction
**Finance - 2013**

The MMI receives core funding from the Deputy Vice-Chancellor (Research) 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 Platform Support Program. The breakdown of MMI’s income and expenditure is detailed below.

### INCOME

<table>
<thead>
<tr>
<th>Description</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Core University funding</td>
<td>1,040,000.00</td>
</tr>
<tr>
<td>Supplementary University funding (for technical support program)</td>
<td>246,000.00</td>
</tr>
<tr>
<td>Strategic University funding</td>
<td>0.00</td>
</tr>
<tr>
<td>Other internal funding</td>
<td>70,677.00</td>
</tr>
<tr>
<td>External funding</td>
<td>3,683.00</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>$1,360,361.00</strong></td>
</tr>
</tbody>
</table>

### EXPENDITURE

<table>
<thead>
<tr>
<th>Description</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating expenditure</td>
<td>585,535.00</td>
</tr>
<tr>
<td>Salaries</td>
<td>529,002.00</td>
</tr>
<tr>
<td>Administration and other costs</td>
<td>56,332.00</td>
</tr>
<tr>
<td><strong>Research enabling expenditure</strong></td>
<td><strong>764,726.00</strong></td>
</tr>
<tr>
<td>MMI administered funds</td>
<td></td>
</tr>
<tr>
<td>Technical support program</td>
<td>345,185.00</td>
</tr>
<tr>
<td>Partnership development</td>
<td>10,775.00</td>
</tr>
<tr>
<td>Research events and promotions</td>
<td>8,716.00</td>
</tr>
<tr>
<td>MCN Access Scheme - Pre-paid time</td>
<td>55,380.00</td>
</tr>
<tr>
<td>Distributed funds</td>
<td></td>
</tr>
<tr>
<td>Interdisciplinary Seed Funding</td>
<td>210,000.00</td>
</tr>
<tr>
<td>PhD scholarships</td>
<td>39,664.00</td>
</tr>
<tr>
<td>Workshop support</td>
<td>19,975.00</td>
</tr>
<tr>
<td>MCN Access Scheme - Merit-based time</td>
<td>4620.00</td>
</tr>
<tr>
<td>Journal cover publication support</td>
<td>7,000.00</td>
</tr>
<tr>
<td>Theme support</td>
<td>31,817.00</td>
</tr>
<tr>
<td>Other research support</td>
<td>40,310.00</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>$1,350,261.00</strong></td>
</tr>
</tbody>
</table>
Finance - January - June 2014

A number of the activities in the final six months of the MMI provided support past the end of the MMI. These included the seed funding, technical support program, and PhD scholarships. As a result the expenditure in 2014 is similar to previous years although carry forward from previous years has allowed the six months funding in 2014 to be sufficient to meet the costs.

<table>
<thead>
<tr>
<th>INCOME</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Core University funding</td>
<td>425 000.00</td>
</tr>
<tr>
<td>Supplementary University funding (for technical support program)</td>
<td>50 000.00</td>
</tr>
<tr>
<td>Other internal funding</td>
<td>50 000.00</td>
</tr>
<tr>
<td>External funding</td>
<td>17 260.39</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>$507 260.39</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>EXPENDITURE</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating expenditure</td>
<td>224 334.28</td>
</tr>
<tr>
<td>Salaries</td>
<td>214 954.14</td>
</tr>
<tr>
<td>Administration and other costs</td>
<td>9 380.14</td>
</tr>
<tr>
<td><strong>Research enabling expenditure</strong></td>
<td>912 713.64</td>
</tr>
<tr>
<td>MMI administered funds</td>
<td></td>
</tr>
<tr>
<td>Technical support program</td>
<td>359 458.93</td>
</tr>
<tr>
<td>Research events and promotions</td>
<td>3 027.37</td>
</tr>
<tr>
<td>MCN Access Scheme - Pre-paid time</td>
<td>-9 460.00</td>
</tr>
<tr>
<td>Distributed funds</td>
<td></td>
</tr>
<tr>
<td>Interdisciplinary Seed Funding</td>
<td>220 000.00</td>
</tr>
<tr>
<td>PhD scholarships</td>
<td>66 807.99</td>
</tr>
<tr>
<td>Strategic research support - new appointment Professor Ken Crozier</td>
<td>100 000.00</td>
</tr>
<tr>
<td>Workshop support</td>
<td>22 471.18</td>
</tr>
<tr>
<td>Visiting fellows</td>
<td>15 000.00</td>
</tr>
<tr>
<td>Journal cover publication support</td>
<td>2 000.00</td>
</tr>
<tr>
<td>Theme support</td>
<td>18 568.45</td>
</tr>
<tr>
<td>Other research support</td>
<td>114 839.72</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>$1 137 047.92</strong></td>
</tr>
</tbody>
</table>
MMI team

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

Deputy Director
Ray Dagastine
Tel: +61 3 8344 4704
Email: rrd@unimelb.edu.au

Manager
Gaby Bright
Tel: +61 3 8344 7605
Email: gbright@unimelb.edu.au

Technical Support Coordinator
Lauren Hyde
Tel: +61 3 8344 0176
Email: lauren.hyde@unimelb.edu.au

Industry Partnerships Coordinator
Noel Dunlop
Tel: +61 3 9035 3828
Email: n.dunlop@unimelb.edu.au

Technical Support Officer
(Nanofabrication)
Dan Smith
Tel: +61 3 9902 4377
Email: dan.smith@nanomelbourne.com

Project and Administration Officer
Lilian Tan
Tel: +61 3 9035 7445
Email: lj.tan@unimelb.edu.au

Technical Support Officer
(Advanced Fluorescence Imaging)
Benjamin Hibbs
Tel: +61 3 9035 7749
Email: benjamin.hibbs@unimelb.edu.au

Finance and administration support
Hana Crsip, Karla Fallon, Ben Hess
Tel: +61 3 8344 6415
Email: mmi-office@unimelb.edu.au

Platform Support Officer
(Nanomaterials Characterisation)
Marta Redrado Notivoli
Tel: +61 3 9035 8587
Email: martar@unimelb.edu.au
General enquiries
Tel: +61 3 8344 6415
Fax: +61 3 9347 4783
Email: materials-info@unimelb.edu.au
Web: www.materials.unimelb.edu.au

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

How to find us

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

First row:

Second row:

Third row:
Novel drug carriers: from grafted polymers to cross-linked vesicles

Quantitative formation of core cross-linked star polymers via a one-pot two-step single electron transfer-living radical polymerization