



Australian Nanotechnology Network

Annual Report
2014



Australian Nanotechnology Network

ANNUAL REPORT 2014

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MISSION STATEMENT AND OBJECTIVES

Mission Statement

The Mission statement of the Australian Nanotechnology Network is to enhance Australia's Research in Nanotechnology and related areas, by effectively promoting and drawing together collaborations in this field.

This innovative network was created by four seed funding networks joining together in order to cover the broader areas and to create a larger more effective network.

The Australian Research Council funding came to an end in 2010. ANN received funding from the Department of Innovation, Industry, Science and Research towards the continuation of network operations until the end of 2013.

The following institutions are also contributing to the funding of the network operations which will be continuing.

Australian National University, ANSTO, CSIRO, DSTO, Deakin University, Flinders University, Griffith University, LaTrobe University, Monash University, Queensland University of Technology, RMIT, University of Melbourne, University of Newcastle, University of New South Wales, University of Queensland, University of South Australia, University of Sydney, University of Technology Sydney, University of Western Australia, University of Wollongong

Objectives

The Nanotechnology field is one of the fastest growing areas of research and technology. The Australian Nanotechnology Network is dedicated to substantially enhancing Australia's research outcomes in this important field by promoting effective collaborations, exposing researchers to alternative and complementary approaches from other fields, encouraging forums for postgraduate students and early career researchers, increasing nanotechnology infrastructure, enhancing awareness of existing infrastructure, and promoting international links. The ANN will achieve these goals through its dedication to bringing together all the various groups working in the field of Nanotechnology and related areas within Australia.

The Network aims to:

1. bring together key groups working in this area to communicate, innovate, share and exploit mutual strengths and facilities to make a major impact internationally
2. identify new areas of research
3. highlight the infrastructure that is available in Australia and promote use and sharing of these facilities
4. identify infrastructure needs to strengthen research
5. leverage off and interact with other networks for mutual benefit
6. develop industry and international links
7. interact with the wider community
8. encourage postgraduate students and early career researchers to enhance their skill base and training
9. become a national resource for industry, research and educational institutions, government and policy developers

2014 in Review

The work in 2014 was focused on enhancing the funding of programs and events related to Nanotechnology around the country.

Membership of 1310, participants including 759 post graduate students and Early Career Researchers. More than 265 research groups are participating in the Network.

Over 5,600,000 Website hits

Held the International Conference on Nanoscience and Nanotechnology

Held the ANN Early Career Researcher Workshop

3 Young Nano Ambassador Awards

1 Short Term Visit

10 Overseas Travel Fellowships

7 Events Sponsored by ANN

Structure and Management

The Australian Nanotechnology Network is managed by a Management Committee which met twice during 2014. The meetings were held in February at the Adelaide Convention Centre during the International Conference on Nanoscience and Nanotechnology and in November at the Research School of Physics and Engineering at ANU.

This management committee represents the wider membership and is chaired by an independent chair. The committee determines the priorities for each activity and allocates the budget for the network. A Network Manager manages the day to day administrative tasks under the Guidance of the Network Convenor.

Management Committee Chair

The duties of the Chair are to chair Management committee meetings, provide advice to the Network, confirm meeting minutes for circulation to Management committee members, represent the network at important meetings and provide general guidance to the network management. The current chair is Professor Erich Weigold.

Convenor

The convenor has overall responsibility for the Network operations and for meeting ARC requirements and guidelines. Represent the network at key Nanotechnology meetings in Australia and key International network meetings. Supervise Network staff and provide overall direction to the network activities. The network Convenor is Professor Chennupati Jagadish.

Management Committee Members

The management committee members participate in committee meetings. They serve on the Working Group sub committees, represent the Network and publicise network activities, organise and actively participate in the management of network activities, act as ambassadors for the Network and provide advice to the network members about network programs.

Working Groups

Committee members form into working groups that assess funding applications and other issues prior to the matter going to the full Management committee for voting. There are four working groups and their areas comprise.

Events Working Group – evaluates all applications for sponsorship funding for Conferences, Workshops, summer and Winter Schools and Short Courses.

Visits Working Group – evaluates all applications for Short and Long Term Visits and Overseas Travel Fellowships.

Outreach Working Group – evaluates outreach proposals such as Public Lectures, Distinguished Lecturers visits, Outreach and Webpage.

Education Working Group – evaluates applications for student, ECR and Entrepreneur Forums and educational activities.

The Convenor fills in if a working group member is unavailable or when there is a conflict of interest.

The Management Committee (MC) comprises of the following members, representing 6 States, students and early career researchers and chaired by an Independent chair. The MC has representatives from ANSTO, CSIRO, DSTO and industry.

Chairman – Emeritus Professor Erich Weigold – Australian National University

Convenor- Prof Chennupati Jagadish - Australian National University

Events Working Group

Prof. Laurie Faraone	University of Western Australia
Prof. Paul Mulvaney	University of Melbourne
Dr Tan Truong	Defence Science and Technology Organisation
Prof. Peter Majewski	University of South Australia
Prof Michael James	Australian Synchrotron
Prof Ian Gentle	University of Queensland

Visits Working Group

A/Prof Adam Micolich	University of New South Wales
Prof. Deb Kane	Macquarie University
Prof Gordon Wallace	University of Wollongong
Ms Siobhan Bradley	University of South Australia

Outreach Working Group

A/Prof Adam Micolich	University of New South Wales
Prof. Deb Kane	Macquarie University

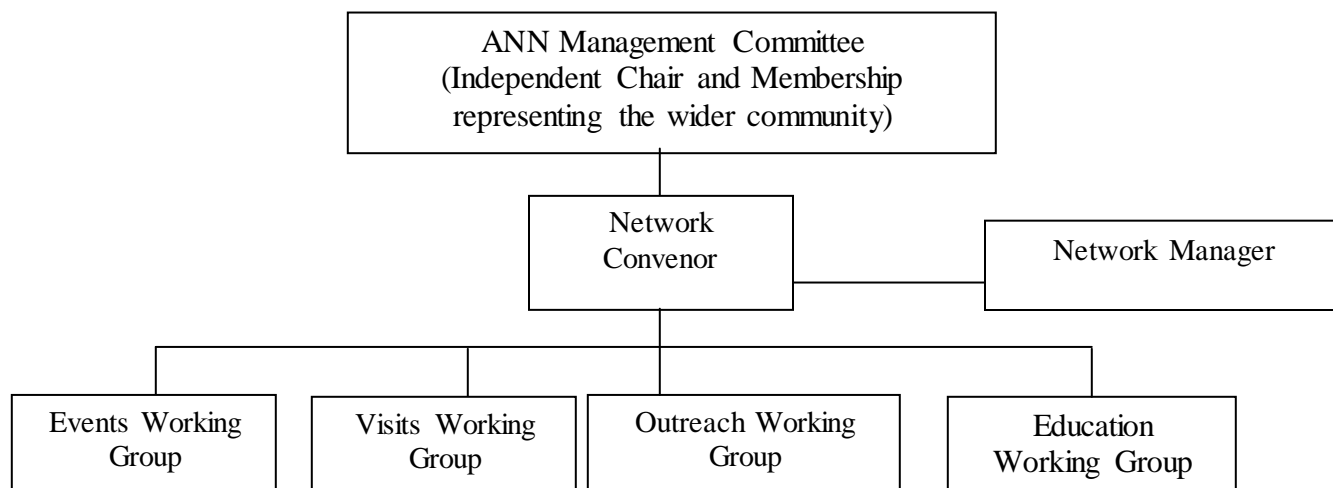
Education Working Group

Prof. Max Lu	University of Queensland
Prof Terry Turney	Micronisers Pty Ltd and Monash University

Industry Working Group

Dr Anita Hill	Commonwealth Scientific and Industrial Research Organisation
A/Prof Paul Wright	RMIT-University, convenor of NanoSafe Australia
Prof David Lewis	Flinders University
Dr Stefan Harrer	IBM
Ms Liz Micallef	Network Manager

ANN Structure



ACTIVITIES UNDERTAKEN BY ANN

List of Activities funded / organized by ANN

International Conference on Nanoscience and Nanotechnology – Adelaide Convention Centre, Adelaide, South Australia, 2-5th February 2014

ANN Early Career Researcher Workshop – University of Technology, Sydney, 10-11th July 2014

Young Nanotechnology Ambassadors program

- Western Australia - Mr Tristan Clemons, Biomedical, Biomolecular and Chemical Sciences at the University of Western Australia
- New South Wales- Ms Katherine Mc Donnell – University of Sydney
- Victoria –Mr Bartłomiej Kolodziejczyk- Monash University

Short Term Visits

- Mr Damon Carrad – Univeristy of New South Wales

Overseas Travel Fellowships

- Mr Chris Baldwin from Macquarie University visit to Harvard University
- Mr Keng Chan from the Australian National University visit to Oslo University
- Mr Phillipp Gutruf from RMIT University visit to the University of Illinois
- Mr Roman Lyttleton from the University of New South Wales visit to Lund University
- Mr Tushar Kumeira from the University of Adelaide visit to the University of California
- Miss Katie Chong from the Australian National University visit to Sandia National Laboratories, New Mexico, USA
- Mr Steven Harris Wibowo from the University of Melbourne visit to IBM Almaden Research Centre, California, USA.
- Mr Majid Mortazavi from Monash University visit to the University of Pennsylvania, USA.
- Dr Anthony Chesman from CSIRO visit to Columbia University USA
- Mr Fenlong Wang from the Unversity of New South Wales to visit the Max Plank Institute for Polymer Institute, Germany.

Workshops and Events Sponsored by ANN

- Advanced Nanomaterials Workshop held on the 30-31st January 2014 at the University of Melbourne
- 5th International NanoMedicine Conference held at Coogee Beach in Sydney on the 30th June-2nd July 2014
- NanoBio Australia 2014 held on the 6-10 July 2014 at the University of Queensland
- ANN Early Career Workshop held on the 10 - 11/07/2014 at the Guthrie Theatre, University of Technology , Sydney
- Molecular Modelling 2014: From Biomolecules to Materials held at the Lamington National Park, Gold Coast on the 31st July to 2 August 2014
- 3rd Biennial Conference of the Combined Australian Materials Societies - CAMS 2014 held at the University of Sydney on the 26-28 November 2014
- Conference on Conference on Optoelectronic and Microelectronic Materials and Devices (COMMAD2014) held at the University of Western Australia on the 14-17 December 2014

International Conference on Nanoscience and Nanotechnology held at the Adelaide Convention Centre on the 2-6th February 2014



<http://www.aomevents.com/ACMMICONN>

Another successful conference was held in Adelaide in February 2014 and this combined conference with the Australian Conference on Microscopy and Microanalysis attracted eight hundred and seventy seven delegates from twenty one countries.

The conference was chaired by Prof Tanya Monro and Dr Angus Netting from the University of Adelaide. This year's conference themes, symposia chairs and co chairs included the following.

Nanomaterials

Chair: Jim Williams - Australian National University

Co-Chairs:

Peter Majewski - University of South Australia

Amanda Ellis - Flinders University

Jeff McCallum - University of Melbourne

Colin Raston - Flinders University

Michael Cortie - University of Technology, Sydney

Nanobiotechnology

Chair: Frank Caruso - University of Melbourne

Co-Chairs:

Gordon Wallace - University Of Wollongong

Justin Gooding - University of New South Wales

Jin Dayong - Macquarie University

Hans Griesser - University of South Australia

Alexandre Francois - University of Adelaide

Nanoelectronics

Chair: Sven Rogge - University of New South Wales

Co-Chairs:

Adam Micolich - University of New South Wales

Michael Fuhrer - Monash University

Arkady Fedorov - University of Queensland

David Reilly - University of Sydney

Nanophotonics

Chair: Hark Hoe Tan - Australia's National University

Co-Chairs:

Paul Mulvaney - University of Melbourne

Heike Ebendorff-Heidepriem - University of Adelaide

Laurie Faraone - University of Western Australia

Deb Kane - Macquarie University

Min Gu - Swinburne University of Technology

Peter Reece - University of New South Wales

Computational Nanotechnology

Chair: Julian Gale - Curtin University Australia

Co-Chairs:

Debra Berhardt - University of Queensland

Amanda Bernard - Commonwealth Scientific and Industrial Research Organisation

Irene Yarovsky - RMIT University

Mike Ford - University of Technology, Sydney

Nanocharacterisation

Chair: Joe Shapter - Flinders University

Co-Chairs:

Joanne Etheridge - Monash University

Ian Gentle - University of Queensland

Paul Munro - University of New South Wales

Jenny Wong-Leung - Australia's national university

Matthew Phillips - University of Technology, Sydney

Michael James - Australian Nuclear Science and Technology Organisation

Nanotechnology for Energy and Environment

Chair: Rose Amal - University of New South Wales

Co-Chairs:

Yibing Cheng - Monash University

Lan Fu - Australia's National University

Wey Yang Teoh - City University of Hongkong

Lianzhou Wang - University of Queensland

Kondo-Francois Aguey-Zinsou

Anita Hill

Commercialisation of Nanotechnology

Chair: David Lewis - Flinders University

Co-Chairs:

Maxine McCall - Commonwealth Scientific and Industrial Research Organisation

Geoff Spinks - University of Wollongong

Howard Morris - Safe Work Australia

ICONN hosted a short course on the Introduction to Nano-fabrication Technologies on the first day organised and featured speakers from the Australian National Fabrication facility.

ICONN featured five plenary talks, thirty eight invited talks and 800 oral and poster presentations. Plenary and invited speakers gave a remarkable synopsis of recent developments in the field.

ICONN 2014 plenary speakers:

- Professor Masakazu Aono - National Institute for Material Sciences, Japan
- Professor Jeremy Baumberg - University of Cambridge, UK
- Professor Lorenzo Pavesi, University of Trento, Italy
- Dr Eliza De Ranieri, Nature Nanotechnology
- Professor Michael Strano – MIT, USA

The conference Sponsors and Exhibitors were:

Platinum Sponsor -FEI

Gold Sponsors - Zeiss, AXT, JOEL, TESCAN, Hitachi.

Technology Hub & Speaker Sponsor - Australian Microscopy and Microanalysis Research Facility

Silver Sponsors – Bruker, Government of South Australia

Bronze Sponsor – Realtek, EVG, CSIRO

Conference Sponsors – Australian National Fabrication Facility, University of South Australia, the University of Adelaide

Lanyard Sponsor – Institute for Photonics and Advanced Sensing

ICONN Session Sponsor – Centre for Advanced Nanomaterials

Conference Wine Sponsor – Serafino Wines

Supporter – American Elements, Nanovea

Technical Sponsors – IEEE, Electron Devices Society

Exhibitors

Agilent Technologies, BOC, Boeckeler Instruments Inc, Cameca, Centre for Nanoscale Biophotonics (CNBP), Coherent Scientific, EDAX Inc., Emgrid Australia Pty Ltd, Gatan HREM Research, IPAS, John Morris Scientific, Lastek, Leica Microsystems, Oxford Instruments PerkinElmer, ProSciTech, SPECS Surface Nano Analysis GmbH, Scitech, Scitek, Technoorg Linda Co Ltd, The Innovation Group & Asylum Research, an Oxford Instruments company Thomson Scientific Instruments, Warsash Scientific, WITec GmbH

Trade Displays

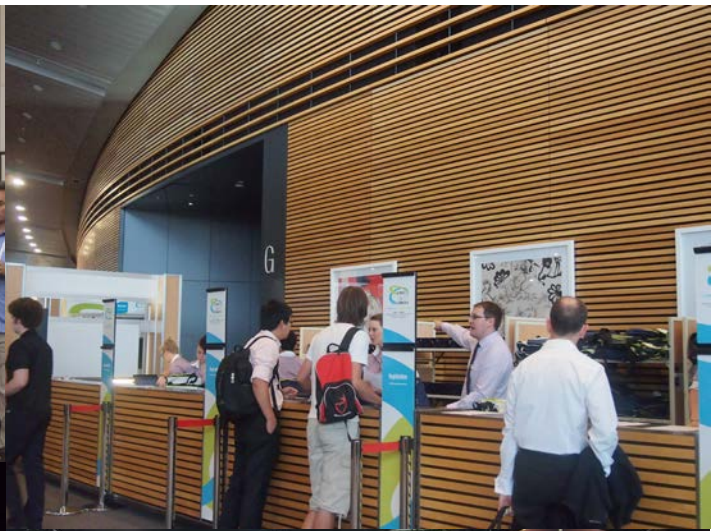
Life Technologies, Resonate Acoustics, Thermo Fisher Scientific

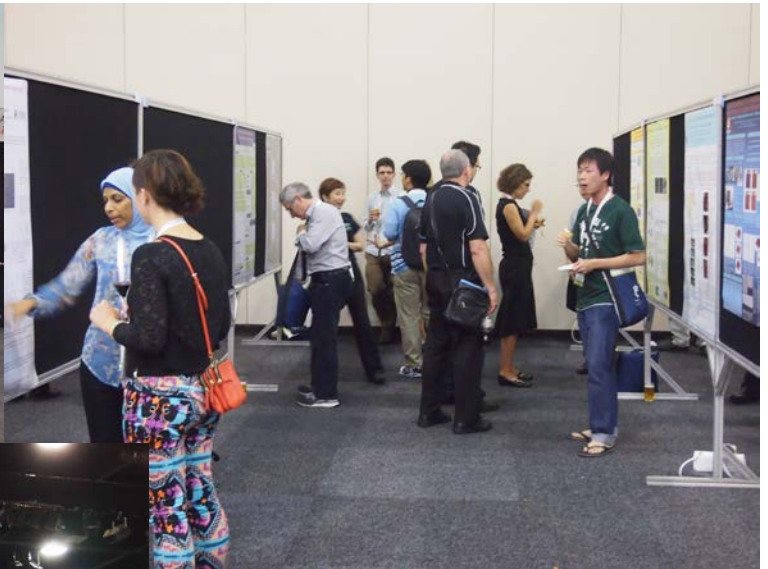
Demographics

Country	
AUSTRALIA	670
AUSTRIA	4
BELGIUM	2
CANADA	2
CHINA	7
CZECH REPUBLIC	4
DANMARK	2
DEUTSCHLAND	22
ESTONIA	1
FINLAND	1
FRANCE	4
HUNGARY	1
INDIA	2
ITALY	3
JAPAN	28
KOREA	15
MALAYSIA	4
MEXICO	2
NEDERLAND	10
NEW ZEALAND	10
CHINA	3
REPUBLIC OF KOREA	5
SAUDI ARABIA	5
SINGAPORE	5
SWEDEN	2
SWITZERLAND	3
TAIWAN	2
THAILAND	1
THE NETHERLANDS	3
TURKEY	2
U S	34
UK	17
Participants	877



ICONN 2016 will be held in February 2016 in Canberra.





ANN Early Career Workshop held on the 10 - 11/07/2014 at the Guthrie Theatre, University of Technology, and Sydney.

In July 2014, UTS hosted the annual meeting for Early Career Researchers. It was the largest meeting so far, encompassing more than 100 registered PhD students and early career researchers. The meeting has a large breadth of topics covering variety spanning bio-nanomedicine, nanofabrication, nanophotonics and nanocatalysis that were presented as Oral or Poster presentations. The workshop was co chaired by Dr Igor Aharanovic (UTS), Dr Charlene Lobo (UTS), and Ms Siobhan Bradley (UniSA).

Keynote Speakers:

Prof Francois Ladouceur - University of New South Wales

A/Prof Heike Ebendorff-Heiderpriem - The University of Adelaide

A/Prof Lan Fu - Australian National University

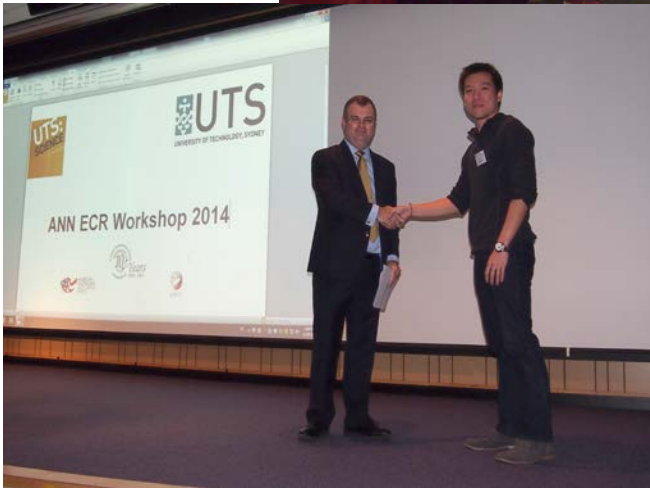
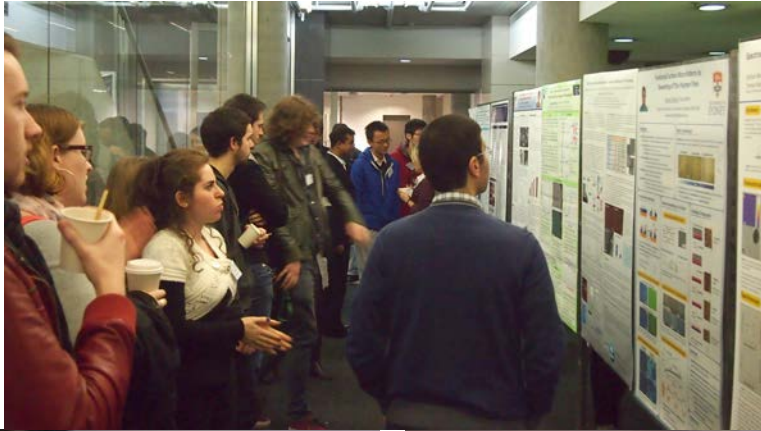
Dr Danielle Kennedy - CSIRO



The meeting also had a first of its kind "career focused" panel that enabled direct Q&A sessions with industry leaders who were once PhD students or young postdoctoral fellows and then moved away from academia. A few names to mention are Dr James Rabeau - now a strategy analyst and A/Prof François Ladouceur - now a successful entrepreneur.

The BBQ dinner was probably the highlight of the meeting for many of the attendees. It was an excellent ice breaker and allowed easy communication and networking. Overall, the meeting was a great success that certainly brought the nanotechnology community closer together and opened new doors for collaboration and professional development.





YOUNG NANO AMBASSADOR AWARDS

YOUNG NANOTECHNOLOGY AMBASSADOR AWARDS

The Young Nanotechnology Ambassador Awards were set up to promote science and science education in state and territory schools. Two awards are provided per state/territory and each award is valued up to \$2000.

The young nanotechnology ambassadors are required to visit a minimum of four schools (preferably at least one regional school) to inspire students about nanotechnology, and more broadly science education. It is up to the ambassadors to decide which schools they visit and to arrange these visits with the schools. The ambassadors are encouraged to present a talk which could include visual demonstrations or simple experiments, slide shows or other multimedia presentations.

The following are the Young Nanoscience Ambassadors for 2014

Queensland - Mr Amirali Popat from the Australian Institute for Bioengineering and Nanotechnology University of Queensland

Amirali will be finishing the school visits in 2015

South Australia - Mr Jakob Andersson from the Chemical and Physical Sciences at Flinders University

Jakob will be visiting the schools in 2015

New South Wales- Ms Katherine Mc Donnell – University of Sydney

Visits to Schools will take place in 2015

Victoria –Mr Bartłomiej Kolodziejczyk- Monash University

Bartłomiej will be visiting the schools in 2015

Can Science Take You on a Donkey Ride? -Tristan Clemons

Nanotechnology School outreach from the remote Kimberly region to the southwest of Western Australia

Science Week 2014 has been my most exciting yet. I decided this year to use the support from the Australian Nanotechnology Network (ANN) and the University of Western Australia (UWA) to do a series of presentations and demonstrations to school children of a range of levels from primary school right through to high school in order to excite students about nanotechnology during Science Week 2014.

This incorporated a range of events and amazing experiences I was fortunate enough to be involved in. I chose to deliver a presentation to students (varying the content depending on the age/ability level I was presenting to) but my talk this year entitled **'Can Science Take you on a donkey ride?'** was all based around a picture taken of me having a blast while riding a donkey while in Greece for a conference (Figure 1). This 'donkey ride' was an opportunity I would not have had if not for science and my research and I wanted to get this message across to students through depicting some of the amazing experiences I have been lucky to have been afforded in my short career to date.



The theme of the presentation was to show students my pathway from my own school days, right through to finally completing my PhD in developing nanoparticles for drug delivery this year at the University of Western Australia. In this presentation I had many personal anecdotes, photos, videos and also some demonstrations of some of the amazing capabilities of a range of materials which have been modified on the nanoscale.

Figure 1 – Riding a donkey at Lindos on the Greek island of Rhodes, the inspiration behind my title of 'Can Science Take You on a Donkey Ride?'

Visit to Western Australia's Kimberly region

I was fortunate enough to team up with UWA's SPICE program, a program designed to enrich the secondary science experience in schools across Western Australia (WA), to visit two remote schools in the west Kimberly region of WA (Note: for more information on the program, head here: <http://spice.wa.edu.au/>).

These schools and students located approximately 2,000 km from Perth were very excited to have a 'scientist' visiting as a part of National Science Week, an opportunity unfortunately they are afforded only very rarely due to the remoteness of the communities. The first school we visited was the Christ the King Lombadina Mission School (Figure 2A and B), where the students were not only keen to hear about my story and nanotechnology but were also very excited to have a kick of the aussie rules football with their new guest, an excitement I was only all too happy to share with the students throughout the day.

The second school we visited was the One Arm Point Community School, a school where again we were welcomed and the students were very attentive to hear about my research and the role nanotechnology can play in the future. The students were also pretty keen to have me on their basketball team at lunchtime which also helped me find a few friends in the school (Figure 2C). In summary, I am very thankful to the Bardi people and the community for sharing their culture and allowing us to visit both of these remote schools and to see the amazing and unique country which is on display in WA's Kimberly region (Figure 2D).



Figure 2 – A) Picture of the entryway to the school and to the right original church of the Lombadina Mission Community, B) Presenting to students from Christ the King Lombadina Community School, C) Getting a bit of basketball in with the boys at lunchtime while at One Arm Point, D) A photo taken at Kooljiman as the sun was setting.

Nanotechnology Outreach in the South West of Western Australia

Upon returning from the Kimberly I then went 2 hours drive south of Perth to Bunbury, a country town to visit a number of schools to present and discuss nanotechnology with a range of students. While in the southwest I visited St. Mary's Primary school and spoke with the year

7 class, I was humbled to be a special guest and deliver the keynote address at the Newton Moore Senior High school Science Fair and spoke to a number of classes at both Bunbury Catholic College and Australind Senior High school while in the region. During these demonstrations I found it was very important to share my own stories with respect to navigating a pathway from school into science, students of all ages but especially those currently looking at finishing their secondary schooling in the near future were very interested to hear my story with regards to choosing subjects, a university and a degree to study as at times this can seem like an overwhelming process. Through intertwining these stories amongst demonstrations of some interesting nanomaterials and discussions about my own research and results I was able to keep student attention throughout my presentations (at least it seemed that way anyway) I would like to also thank all the Science teachers and schools with which I visited for their help in organising the visits and classes to ensure everything run smoothly while I was in Bunbury, it was much appreciated.



Figure 3 – A) Showing students the magnetic properties of a ferrofluid. B) About to begin my presentation to the year 7's at St. Mary's Catholic Primary School. C) Speaking with a few students from Newton Moore Senior High school at their science fair event. D) Presenting at Bunbury Catholic College.

Short Term Visits

SHORT TERM VISITS

Funding support is also available to **postgraduate students** and **early career researchers** (within 5 years of award of PhD degree) for travel and accommodation expenses associated with Short Term Visits to research Institutions within Australia. Up to \$1,000 is provided for travel and accommodation to a location(s) within Australia.

Mr Damon Carrad from the University of New South Wales visit to the University of Queensland.

Damon Carrad: Report of Short Term Visit to University of Queensland

The purpose of this visit was to investigate the performance of nanowire transistors featuring a polymer electrolyte gate as a function of water content. The major interest was using these devices as a tool for investigating proton conduction in polyethylene oxide (PEO). In previous work, I had established the ability to nano-scale pattern PEO containing LiClO₄ and used this as a gate dielectric for nanowire transistors.

In these transistors, Li⁺ and ClO₄⁻ ions move through the PEO matrix in response to an applied gate voltage, and transfer the gate charge to ~1 nm away from the nanowire transistor channel. The electric field that results from dropping the gate voltage across only 1 nm gives very effective gating. As a control experiment, I previously fabricated devices *without* LiClO₄ expecting that these devices would either not work at all, or behave poorly in comparison to devices with LiClO₄ incorporation. However, I found that the devices without LiClO₄ behaved just as well as those with LiClO₄, which strongly suggested the presence of a mobile ionic species within pure PEO.

Our hypothesis was that the gating action is mediated by H⁺/OH ions in the PEO, as it is a known hygroscopic material with a high water uptake. A number of other materials exhibiting proton conduction are under investigation by other groups, due to their interest in relation to biological systems. In these materials, water content is usually a major contributor to the parameters of proton conduction (e.g. H⁺/OH density, mobility, conductivity) since H₂O usually either donates protons for conduction or alters the polymer chemistry. It was therefore necessary to quantify the behaviour of my PEO gate dielectric as a function of water content; I accomplished this during my visit to UQ, working closely with Bernard Mostert, a post-doc in Prof. Paul Meredith's group.

Through their previous work with melanins – another class of material supporting protonic transport– Bernard and Paul developed a specialised apparatus to perform electrical measurements under an atmosphere with variable, but tightly controlled water vapour pressure. The system is capable of measurements under atmospheres from vacuum up to complete water vapour saturation, with control of water vapour pressure down to the nearest

mbar. This allowed us to measure many different device properties with excellent reproducibility and precision. During my time at UQ, we were able to quickly establish that across the entire range of hydration levels, devices with and without LiClO₄ have almost identical behaviour, suggesting that H⁺/OH transport dominates even in the devices incorporating LiClO₄. This is true for both qualitative and *quantitative* trends; transistor properties such as subthreshold swing, hysteresis and saturation current varied little between devices. We built on this strong result by developing further experiments to target specific properties of the conducting protons in PEO, e.g. the ionic conductivity, density and mobility.

Bernard and I worked well together, with his knowledge of the water vapour system and polymer chemistry and my knowledge of low-noise measurements of nano-scale electronic devices forming a good complement. We each learned a lot from each other, which was a major bonus from the trip. This is already being put to good use, as Bernard is currently using his new knowledge of my nano-scale transistors to complete some experiments that we were unable to get to in the time I was at UQ.

In turn, his experience with proton conducting polymers is invaluable to understanding the physical processes involved in PEO. Together, we will be able to work effectively across the Sydney/Brisbane distance to complete other experiments to further investigate the role of proton conduction in PEO.

My short term visit was very productive and produced results in number and quality that greatly exceeded my initial expectations. I would really like to thank ANN for the funding that helped make it happen.

OVERSEAS TRAVEL FELLOWSHIPS

OVERSEAS TRAVEL FELLOWSHIPS

Opportunities for five to six Overseas Travel Fellowships valued at up to \$5,000 each are offered every 6 months. This is a mechanism whereby Australian students and early career researchers can visit overseas laboratories to gain new skills and training in this emerging field of research. These fellowships are also offered for attending International Summer Schools of minimum one week duration, or longer.

Applications are ranked and Fellowships awarded to the top 5-6 ranked applications.

Mr Behnam Akhavan from the University of South Australia visit to the Max Planck Institute for Polymer Research, Mainz, Germany.

February 15th 2014 - July 15th 2014

Structural characterization of acrylic acid plasma polymer films via optical wave guide/surface plasmon resonance spectroscopy

Although plasma polymerized films are conventionally known to show a laterally homogeneous structure, very limited knowledge is available regarding the concealed underlying layers of these films. Studying the near-substrate layer properties of a plasma polymerized film represents particular challenges due to the inaccessibility of these buried layers. During my visit to Germany, I however evaluated the structural homogeneity of plasma polymer films at their different depths. Such novel investigation was facilitated by running a joint project between University of South Australia, Max Planck Institute of Polymer Research (MPIP), and Fraunhofer Institute of Microtechnique- Mainz (IMM) owing to the financial support of Australian Nanotechnology Network (ANN) through Overseas Travel Fellowship. The fabrication of plasma polymer coated samples were carried out at IMM, while characterizing the samples were conducted using a unique custom-built surface plasmon resonance – optical wave guide spectroscopy (SPR/OWS) available at MPIP.

The SPR/OWS device made it possible to study the bulk and near-substrate layers of plasma polymerized acrylic acid (PPAAc) films in a single and non-destructive measurement. PPAAc films were deposited onto gold-coated LaSFNg glass slides under wide ranges of plasma input power (5 – 80 W) and deposition time (8 sec. – 40 min.). Micrometre-thick PPAAc films were analysed by surface plasmon resonance (SPR)/optical waveguide spectroscopy (OWS) in order to examine the variations of crosslinking degree throughout the film (Figure 1).

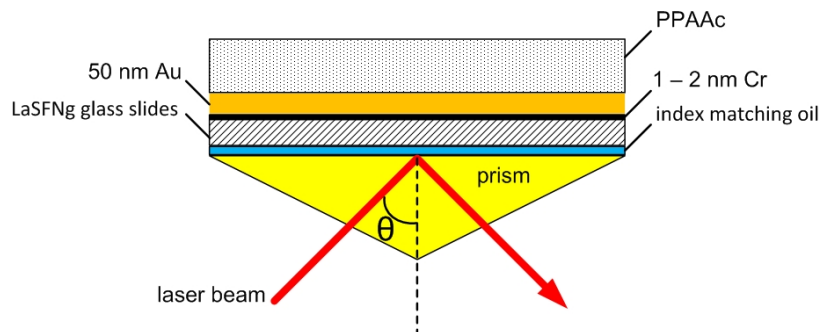


Figure 1. Schematic sample configuration for SPR/OWS measurements

The SPR/OWS reflectivity spectrum of PPAAc film, deposited for 40 minutes (film thickness = 1790 ± 52 nm), is fitted with one- and two-layer models, and shown in Figure 2. As observed, the one-layer model (Figure 2a) can only cover the optical wave guide modes which are indicative of the bulk properties of the film. It is also observed that the surface plasmon resonance peak, indicative of near-substrate layer properties, is recorded at a lower angle than expected for a homogeneous plasma polymerized film. In order to recover the surface plasmon resonance peak, a two-layer model has to be implemented as shown in Figure 2b. This model consists of: (i) a near-substrate layer with a thickness of approximately 200 nm and a refractive index of 1.499, and (ii) the bulk of the film with a refractive index of 1.530. Such a binary model, which fully covers the entire film, suggests the presence of an interphase layer with a lower degree of crosslinking in comparison to the bulk of the film. This behaviour can result from a number of complex factors such as changes of pressure in the vacuum chamber, influence of the substrate and generation of ultraviolet radiation. The findings of this research, which are in contrast to the orthodox view of plasma polymerization process, are of great interest from both practical and fundamental points of view. A paper on these findings is currently under preparation.

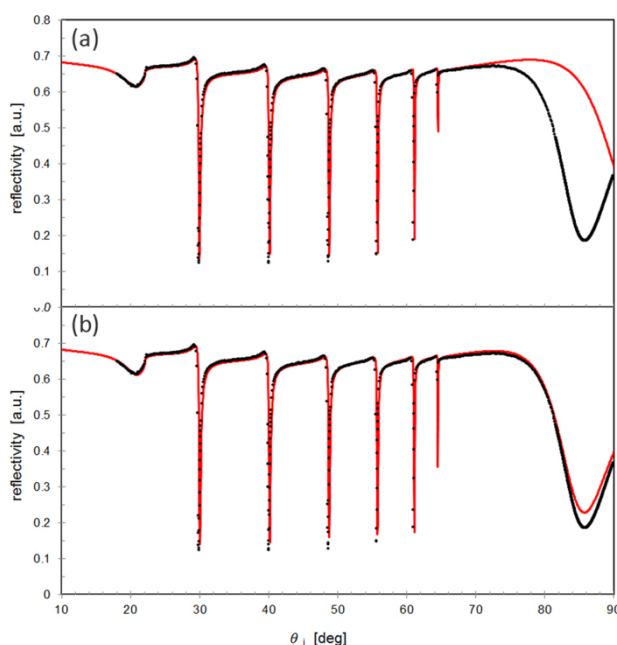


Figure 2. SPR/OWS reflectivity spectrum of PPAAc film (black dots) and fit of the (a) one-layer and (b) two-layer models (continuous red lines). Plasma polymerization conditions: plasma RF power = 10 W, AAc flow rate = 2 sccm, deposition time = 40 minutes.

Other activities during this trip were as follows:

- Preparation of a paper on fabrication of sulfur-rich plasma polymer films deposited on silica particles. This paper has recently been published in Surface and Coatings Technology:

Akhavan, B.; Jarvis, K.; Majewski, P. Plasma polymerization of sulfur-rich and water-stable coatings on silica particles, *Surface Coatings and Technology*, 2015, DOI: 10.1016/j.surfcoat.2015.01.017

- Participation in several meetings and fortnightly seminars of different research groups at Max Planck Institute of Polymer Research and Fraunhofer Institute of Microtechnique.
- Giving an invited talk on current activities at Mawson Institute (UniSA) to Micro4Nano group members at Fraunhofer institute of Microtechnique.
- Presenting at internationally-recognized conferences (funded by UniSA):
 - **Akhavan, B.;** Jarvis, K.; Majewski, P., **Poster:** *Fabrication of nanostructured plasma polymer films for water treatment*, 10th International Nanotechnology Symposium (NanoFair), Dresden, Germany, 1st – 3rd July 2014
(This poster presentation was awarded with the RSC Advances 1st Prize.)
 - **Akhavan, B.;** Jarvis, K.; Majewski, P., **Oral:** *Plasma Polymerisation: A New Approach for the Fabrication of Super-Efficient Adsorbents*, High Tech Plasma Processes (HTPP), Toulouse, France, 22nd – 27th June 2014
 - **Akhavan, B.;** Jarvis, K.; Majewski, P., **Oral:** *Plasma Polymer Coated Particles: A New Class of Adsorbents for Water Purification* The International Conference on Interfaces against Pollution (IAP), Leeuwarden, the Netherlands, 25th – 28th May 2014

In addition to undertaking cutting-edge research at world-class research centers, producing worthwhile results, and publishing in high-ranked journals; the overseas Travel Fellowship allowed me to develop and maintain relationships with internationally-recognized researchers in the field of nanotechnology. It also provided me with a great opportunity to transfer knowledge between our research group in Australia and collaborating researchers in Germany.

Miss Georgia Miller from the University of New South Wales visit to Harvard University, USA.

Report to ANN on outcomes of Overseas Travel Fellowship – Georgia Miller, PhD candidate University of New South Wales

Visiting Fellowship at Harvard University's Program on Science, Technology and Society January – May 2014

The primary focus of my overseas travel was to spend a semester as (non-stipendiary) Visiting Fellow, from 27 January – 30 May 2014, at Harvard University's Program on Science, Technology and Society (STS). This enabled me to work closely with Professor Sheila Jasanoff, who directs the STS Program and is an internationally recognised leader in the field of science and technology regulatory policy and STS studies. This was of great value to me, assisting my comparative analysis of Australian and international approaches to nanotechnology regulation and related public policy debates as part of my PhD work. The fellowship also enabled me to attend a one-week winter school course offered by the Center for Nanotechnology in Society at the Arizona State University, and to conduct twenty two interviews with key US nanotechnology stakeholders as part of my PhD research. I am deeply grateful to ANN for the support for this travel, which has been highly valuable to my PhD research and ongoing academic development.

Visiting Fellow, Program on Science, Technology and Society, Harvard University

The Harvard Program on Science, Technology and Society (STS) is located within the Kennedy School of Government, widely regarded as one of the world's strongest public policy institutions. My semester as a Visiting Fellow enabled me to gain structured exposure to leading STS academic Professor Jasanoff, as part of a group of approximately 12 post-graduate and post-doctoral students from around the world.

My Visiting Fellowship supported advanced training in science and policy studies, including through auditing the post-graduate semester-long course "Law, science and expertise", taught by Professor Jasanoff. The STS Program Fellows held a regular weekly meeting with Professor Jasanoff where we presented our own work-in-progress for feedback and critique, and had the opportunity to learn further about Professor Jasanoff's research. Additionally, the STS Program held weekly STS Circles, where scholars from Harvard, the Massachusetts Institute of Technology, and visitors presented their work. I also had the opportunity to attend regular seminars and lectures organised by Professor Jasanoff for speakers from other universities, public policy groups or other relevant institutions. This range of forums enabled me to gain a far richer understanding of the political, legal and policy context for emerging technologies in the United States, and to better understand the tenor and content of related public policy debates.

Along with two other Fellows, I assisted Professor Jasanoff in organising a one day conference, held at the Kennedy School, "Technological Visions and Revisions: An STS Workshop", at which I made a presentation titled "Vision and revision of nano-futures: Discursive convergence and tension". During my time as a Visiting Fellow I co-wrote a paper evaluating the technical, knowledge-based and political barriers to effective implementation of risk analysis of nanomaterials in Australia and internationally, which has recently been submitted for publication. I have also commenced work on another paper that explores regulatory debates surrounding commercial use of nanomaterials in the Australian context, which I hope to submit for publication

in coming months. Support from ANN is explicitly recognised in both papers and the conference presentation that was made.

The opportunity to present my work-in-progress and interact with other researchers at Harvard, and Visiting Fellows from a wide range of other countries and backgrounds was of immense benefit to me. Given the small size of Australia's science policy and STS communities, this opportunity to spend a semester at one of the key international centres for STS academic work was invaluable in enriching and expanding my understanding of the field and of key theoretical work, and in receiving direct feedback to my own research and analysis.

Winter School, Center for Nanotechnology in Society, Arizona State University

My understanding of cutting edge developments in STS and regulatory fields relating to nanotechnology was further enhanced by my attendance at the "Winter School on the Anticipatory Governance of Emerging Technologies". From 3-10 January, the intensive was organised by The Center for Nanotechnology in Society at Arizona State University (CNS-ASU).

Faculty at the Winter School included researchers from ASU, University of Wisconsin, and the Georgia Institute of Technology. Lectures and training sessions organised by faculty included socio-technical integration research, engagement and participation initiatives, anticipatory governance, meta-data and trend assessment, and ethical dimensions. Additional to lectures, activities include interactive workshops and presentations by students applying anticipatory governance and technology assessment to our own work.

Participation in the Center for Nanotechnology in Society's Winter School helped me to develop relationships with some leading scholars in technology assessment, and to gain a greater understanding of the methodological and theoretical approaches of a key centre for US societal dimensions work on nanotechnology and on responsible innovation. This included those used by the group's sister organisation the Center for Science Policy Outcomes, in Washington DC, which I was subsequently able to visit. Attended by approximately twenty post-graduate and post-doctoral students and early career researchers, the Winter School was also a great opportunity to share and learn with an international cohort.

Research interviews with 22 key United States nanotechnology stakeholders

My semester as a Visiting Fellow also enabled me to conduct archival work, and a series of interviews with twenty two US public policy and nanotechnology experts. I interviewed a range of people who played central roles in securing initial political and funding support for the US National Nanotechnology Initiative during the Clinton administration, and in governance and policy debates in subsequent years. I interviewed nanotechnology stakeholders working in industry, the technical research community, ELSI research, various parts of government, and non-government organisations.

In addition to archival work and document analysis, these interviews will provide an important component of the data I draw on in my PhD thesis. Given the leadership role played by the United States in funding nanotechnology research and in regulatory debates, this research will add great value to the comparative analysis I am undertaking of Australian and international approaches to nanotechnology regulation and related public policy debates.

Dr Ryo Sekine from the University of South Australia visit to Trinity College at Oxford, U.K.

Final report of the visit to Department of Materials, Oxford University

Overview

For a period of 9 weeks, I visited the Department of Materials at the University of Oxford in the United Kingdom to collaborate with Dr. Katie Moore and Professor Chris Grovenor. Our Research aimed to address an increasing concern over the risks associated with the use of engineered nanomaterials (ENM) towards the environment and human health. The primary purpose of the visit was to initiate a research program to three dimensionally analyse the interaction and internalisation of silver nanoparticles (a common ENM) of varying size and surface functionality.

I was fortunate to have been awarded an Australian Nanotechnology Network (ANN) Overseas Travel Fellowship (up to \$4,000) concurrently with the UniSA ECR International Travel Award (up to \$6,000) towards the travel costs. These awards enabled me to visit, learn and image algal cells using Nanoscale Secondary Ion Mass Spectrometry (NanoSIMS) and auxiliary techniques, as well as network with some prominent scientists in the field in the UK. The travel also incorporated visits to a number of key institutes around England: Rothamsted Research and the University of Lancaster that my group currently collaborate with, and enabled me to establish a new collaboration with the Centre for Ecology and Hydrology in Wallingford.

Background and Aims

Engineered nanomaterials (ENM) are unique in their geometrical and quantum mechanical properties and are exploited in many research and industry sectors. At the same time, there is an increasing concern over the risks associated with ENM in that these unique properties may translate to an equally unique impact on organisms. For example, depending on their high surface area and specific surface functionalities, they may adsorb on to the organisms' cell walls, or, due to their extremely small size, may be internalised within the cell. The exact mode or location of interactions could, for example, shed light on the physiological effects that could follow. Currently however, techniques that are capable of elucidating their specific interactions with biological systems are scarce. Electron microscopy based techniques (scanning or transmission electron microscopy) are commonly used, but the projection images that are produced cannot resolve where an ENM may be along the projection axis, i.e. whether they are adsorbed or internalised. The ability to analyse ENM-cell systems three-dimensionally at the single nanoparticle level will therefore be crucial in a definitive, functional understanding of these interactions.

The specific aim of my travel was to realise this key analytical capability using NanoSIMS in collaboration with a world-leading university. Secondary ion mass spectrometry is a destructive technique which allows analysis of the sample layer by layer, with a resolution of <50nm, enabling a three dimensional reconstruction of the site of ENM interaction. Dr. Moore and Prof. Grovenor have expertise in the nanoscale imaging of elemental distributions in biological samples using NanoSIMS and their experience was indispensable in pursuing this aim. Additionally, the Department of Materials has access to advanced analytical equipment that complements the NanoSIMS data and this was a key factor in the selection of the collaborating partners.

Key outcomes

Outcome 1: Identification of specific sample preparation considerations

Sample preparation is an important pre-determinant of the likely success of an imaging or spectroscopic experiment. NanoSIMS was no exception. Several important parameters were identified in the case of Ag-NPs toxicology and algal exposures in preparation for analysis, which deviated from the standard toxicity testing protocols but were crucial in enabling NanoSIMS analysis. These include for example, choice of fixation method, significance of the cell to Ag-NPs number population ratio, identification of mass interferences that may arise with NanoSIMS analysis, and the suitable modifications to the methodology required to overcome this.

Outcome 2: Elemental mapping of algae using NanoSIMS NanoSIMS images of algae exposed to Ag-NPs of two sizes (10 and 60 nm), and two different surface functionalities (tannic acid and polyethyleneimine) were acquired. Significant time was devoted to optimising the detector positions for the 5 detectors, particularly in the case of Ag to avoid the mass interferences. The collected images clearly showed the interaction of Ag-NPs with the algae, particularly in the case of tannic acid-coated Ag-NPs, to be localised on or just inside the outer cell membrane (see Figure 1). Sputtered layer thickness was relatively thick such that 0.5 μm sections were ablated through by only a few layers. Thus, 3D reconstructions had a limited resolution.

Outcome 3: Complementary imaging

Complementary analysis using focused ion beams (FIB) and high resolution SEM were found to be highly beneficial. In most laboratories, these techniques are of limited use as elemental identification at the relevant scales (< 100 nm) is often beyond the capabilities of the technique. However, for high resolution imaging alone, low voltage (1 keV) SEM was superior in the localisation of 10 nm Ag-NPs in the images. These were then correlated with the elemental images acquired on the NanoSIMS to provide convincing evidence for their mode of interactions (Figure 1).

Outcome 4: Networking within the United Kingdom. The travel also provided the opportunity to visit and strengthen collaborations with researchers in England, including new connections with the Centre for Ecology and Hydrology in Wallingford, UK.

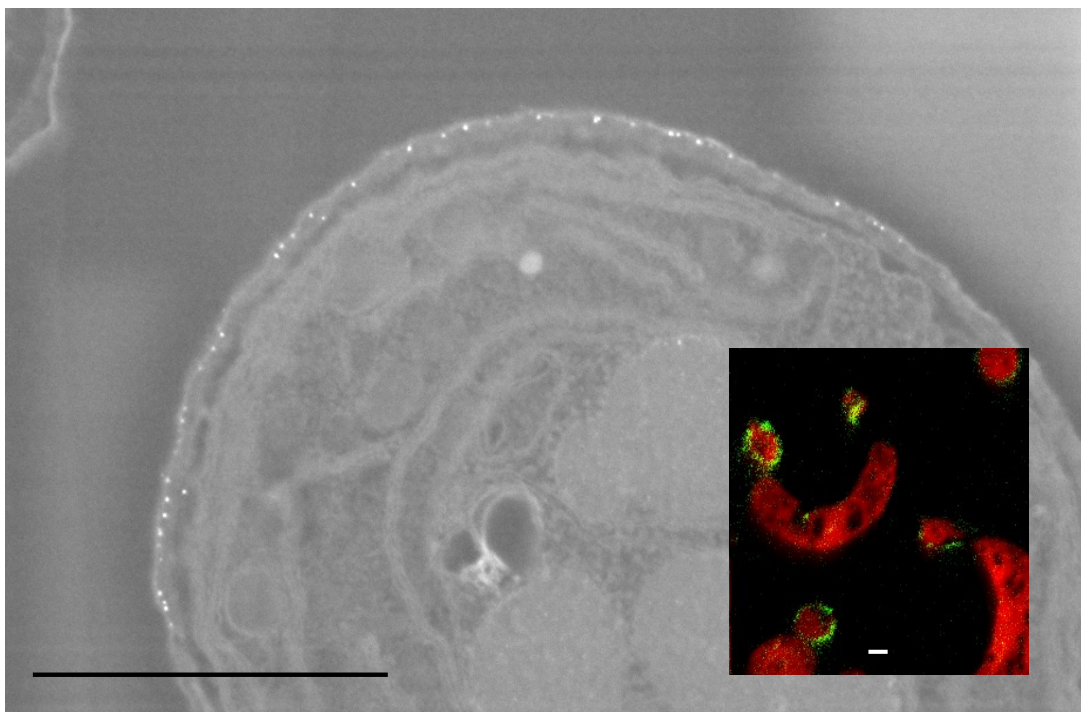


Figure 1. High resolution SEM image of algae exposed to 10 nm tannic acid coated silver nanoparticles. Inset: NanoSIMS images (CN-/Ag- overlay – red/green) of the corresponding algae, providing a clear evidence for interaction of Ag-NPs with the outer cell membrane of algae.

Acknowledgements

I would like to thank the Australian Nanotechnology Network and the University of South Australia for providing me with the opportunity to travel to the UK and work under this scheme. I would also like to thank all members of Professor Grovenor's group of the Department of Materials at the University of Oxford, for welcoming me during this visit, especially to Dr Katie Moore for being a wonderful host, coordinating and facilitating many of the research activities during my visit. Thank you also to Dr Haibo Jiang and Dr Gareth Hughes for their invaluable assistance with FIB and SEM imaging, and Dr Marianne Matzke and Dr Claus Svendsen also for their assistance at CEH Wallingford.

Mr Thomas Keevers from the University of New South Wales visit to the University of Warwick, U.K.

Australian Nanotechnology Network Report: Thomas Keevers, The University of New South Wales

Aims

There is interest in developing commercial electronics, such as solar cells and light-emitting diodes, which are carbon-based (plastics). This is due to their low costs, physical properties (flexibility), and our ability to chemically engineer their properties. The efficiency of these devices depends on the microscopic spin behaviour, which we study directly.

We can directly probe relevant spin-dependent processes using electrically-detected magnetic resonance. At The University of New South Wales, we have developed a custom low magnetic field system for characterizing organic devices under realistic operating conditions. Complimentary high field experiments were performed at The University of Warwick to suppress certain low field effects, and thereby gain greater insight into the microscopic dynamics, such as the role of nuclear polarization.

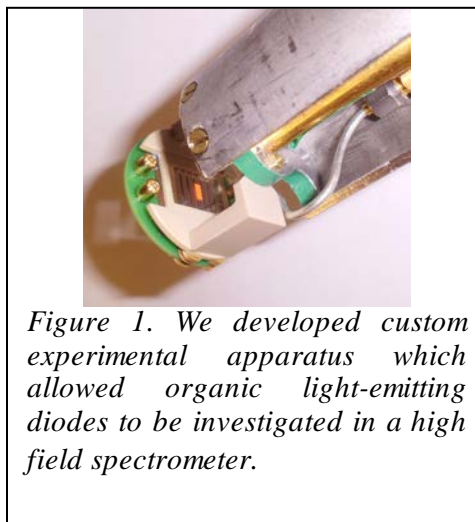


Figure 1. We developed custom experimental apparatus which allowed organic light-emitting diodes to be investigated in a high field spectrometer.

We have previously studied the relaxation pathways in organic materials at x-band (moderate magnetic fields). The 'capstone' of my visit was intended to be measurement of the high field relaxation (T_2). It has been theorized that the interactions of spins with their environment are modified by an external magnetic field. The hyperfine interaction is expected to be important at low fields, with spin-orbit coupling becoming dominant at high fields.

We also studied a variety of organic powders and solutions in a pulsed x-band spectrometer, with the aim of examining their high field behaviour if time permitted. This was to gain fundamental insight into the natural charge carrier behaviour in these materials.

Research timetable

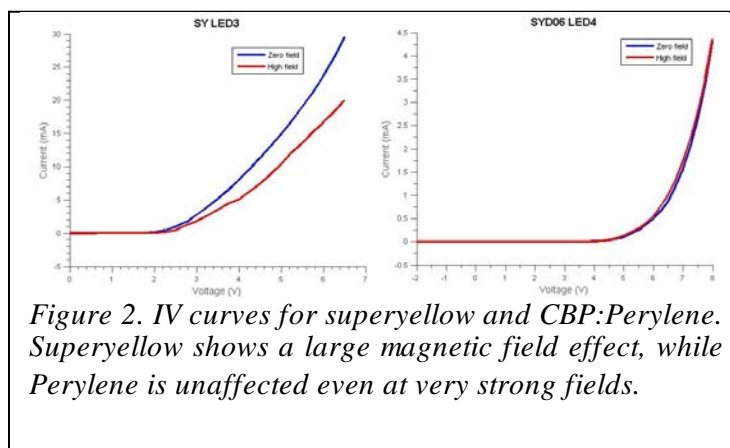
We developed the capability to run our samples in the Warwick High Field ESR spectrometer, and to subsequently perform high field measurements. Time was also spent running organic powders and solutions in an X-band spectrometer.

Pre-trip: Prior to my visit commencing in April, the organic devices were characterised, including IV curves and spectral data. There was also significant liaison between UNSW and Warwick to generate a design for a PCB which would the devices to be readily integrated into their existing setup.

6-10 April: To maximize the utility of this travel, I attended the Royal Society of Chemistry Conference on Electron Spin Resonance in Dundee. This is a leading spin resonance conference.

Week 1-4: Designs for custom parts were submitted to the workshop and the powdered samples were run in an X-band spectrometer. Surprisingly, the powders gave no signal under illumination at 300 or 100K. The lack of charge carrier under illumination by 405, 465 and 532 nm light is puzzling.

Week 5-8: The high field setup was complete and some initial measurements were performed. These were used to refine the experimental setup, so more accurate and reliable data could be collected. This included modifying the holder to reduce the SMP cable length to suppress noise and provide a more reliable connection.



Week 9-12: We performed electrically-detected magnetic resonance on several of our devices at high field. Our devices did not show a strong resonant response, suggesting significant line broadening at high field. This is consistent with the current view that the hyperfine interaction dominates low field, and spin-orbit coupling at high field.

The Virginia Diodes microwave source failed during this period which prevented further resonant experiments. We were able to collect IV curves for our devices at low and high fields and found the device efficiency changed as much as 30% for some of our devices, and less than 1% in others. This may help place limits on the strengths of spin-dependent processes in these devices.

Financial statement

I received support from the Australian Nanotechnology Network, as well as through an Australian Bicentennial Scholarship and my university. The combined support I received was sufficient to cover the flight and the cost of living.

Summary

My project looked at the high field behaviour of organic light-emitting diodes using electrically-detected magnetic resonance. We developed the capability of running our organic devices in the pre-existing high field system. IV curves were recorded at high and low fields, with clear variation between the devices, which we will use to bound the strength of spin-dependent processes. Preliminary resonance spectrum measurements suggest significant line broadening, most likely due to spin-orbit coupling.

Mr Chris Baldwin from Macquarie University visit to Harvard University

Overseas Travel Fellowship - Two-photon UV etching of diamond- Harvard University

September - October 2014- Chris Baldwin

Overview of two-photon etching

Two-photon UV etching of diamond is a process wherein pulsed UV1 irradiation of single crystal diamond surfaces in air at pulse fluences lower than required for laser ablation results in the slow removal of diamond from the surface. The rate of material removal is quadratic with the fluence of the incident light, and appears to be thresholdless, with average rates as low as 3×10^{-9} nm/pulse and as high as 10–3 nm/pulse reported. Material is removed 'gently' with no graphite formation.

For technological applications there are two main challenges: obtaining a reasonable etch rate without causing ablation and roughening of the surface. The fluence which can be used is limited by the ablation threshold, since as the intensity of the etching beam approaches the ablation threshold the probability that the sample will ablate increases. The beam parameters must therefore be selected such that the maximum etch rate is achieved while maintaining a minimal risk of ablation. Two points worth noting are that the quadratic nature of the process means that dialling down the power to reduce risk of ablation can lead to significant reduction in etch rate, and due to the high thermal conductivity of diamond there is no thermal build-up between pulses, so the repetition rate can be increased to boost the etch rate without increasing the risk of ablation.

UV etching also tends to reveal underlying {111} facets (i.e. the {111} surfaces are most slowly etched). This can result in ridge-like structures forming along the intersections of {111} planes. The orientation and morphology of these ridges is dependent on the relationship between the crystal lattice and the etching laser polarisation. The depth and spacing of ridges increases with depth of the etch, and the deepest, longest ridges are formed when the laser polarisation is perpendicular to a {111} intersection. This can result in significant roughening of the surface.

Aims of the visit

The nature of the process which results in material removal is still unknown, and it is the goal of my PhD project to investigate this further. The specific aims of my visit to Harvard were to investigate the effects of etching on nano-structured diamond surfaces, and to assist my supervisor (A/Prof Rich Mildren, who was on sabbatical at Harvard at the time) with STM tip-enhanced etching. The Loncar group at Harvard have great expertise in the fabrication of all manner of diamond nano-structures, mainly via reactive ion etching (RIE), as well as interest in developing new techniques to augment their fabrication capabilities.

STM tip-enhanced etching involves attempting to exploit the local plasmonic enhancement of the electric field when the etching laser is incident on a sharp STM tip, in order to achieve sub-diffraction limited etched features. If achieved, this would not only be a demonstration of a novel method of direct writing sub-diffraction structures, but also allow us to place an upper bound on the minimum resolution which may be achieved, which in turn allows us to infer whether material removal is local with respect to the absorption of photons, or if energy is absorbed and then diffuses some distance. This area of research was my supervisor's primary interest, and unfortunately there were numerous subtleties involved in getting this to work which prohibited any significant progress in the time frame that I was at Harvard.

My primary interest was the investigation of the effects of UV etching on nano-structured diamond surfaces. The question to be answered was as follows: if we irradiate a 3D structure such as a nano-pillar or nano-beam (prepared using state-of-the-art methods at Harvard), will material

removal occur with the same rate on all sides and what sorts of ridge structures will emerge? If etching could be achieved with similar rates on all sides of a nano-structure, then this would allow for very controllable tuning of the dimensions of said structure by as much as hundreds of nanometres. This could be done in ambient conditions, or even in situ while monitoring properties of the structure, such as Q-factor of diamond nano-resonators.

If etching occurs on all sides of a structure, we must then assess the types of polarisation dependent ridges which are formed. Since the ridges which can result from UV etching may be of significant size, the surface quality of a structure may be compromised (which is, of course, a significant problem for many applications). Analysis of how these ridges emerge on a 3D structure is therefore essential in order to assess how this technique might be applied in technological applications. More importantly (from the perspective of my project at least), the way in which ridges form on complex structures may allow us greater insight into how these ridges form, and therefore give us more information about the etching mechanism.

Lab visits

In addition to the experiments at Harvard, several lab visits were organised in order to meet with researchers to both see state of the art facilities and discuss possible future collaborations

Stanford Linear Accelerator Centre (SLAC), Menlo Park, CA

On my way to Boston I stopped over in San Francisco in order to visit SLAC. While there I toured the facilities and learned about both accelerator science and the processes - logistical and administrative - involved in operating such a complex system as an outside user. My host (Dr Eduardo Granados, a staff scientist at SLAC) also displayed an interest in performing experiments using the SLAC main accelerator to perform time resolved near-edge x-ray absorption fine structure (NEXAFS) spectroscopy while etching a sample in situ, in order to gain insight into the electronic processes occurring at the sample surface during etching. We are currently pursuing this opportunity.

Washington DC

Around half way through my time in Boston (30/9/14 to 4/10/14), my supervisor and I drove to Washington DC to visit a number of military labs in DC and the surrounding areas.

Air Force Office of Research and Development (AFOSR) we met with project managers who are Responsible for funding research projects of interest to the Air Force, of which our research group (which is primarily focussed on high power diamond Raman lasers) has recently been a beneficiary. This was an enlightening meeting in which I learned about the processes and politics involved in securing funding.

Army Research Labs (ARL) We visited ARL at Fort Belvoir, Fairfax County, Virginia, and were hosted by Dr Lew Goldberg. As ARL focuses highly on application based research, here we discussed the possible applications of diamond based technologies for the military, as well as what makes a technology successfully transition from the lab to deployment.

Naval Research Labs (NRL) At NRL we were hosted by Dr Brad Pate, who is an active researcher in the diamond field, with particular interests in the chemical and electronic properties of diamond surfaces. We also gave a presentation on our work to a group of NRL staff. While at NRL we discussed our work with Brad, and he offered insights based on his expertise, as well as recommending several references of both papers to read and people to talk to. He also suggested the possibility of a future collaboration at NRL, as they have available a large array of experimental

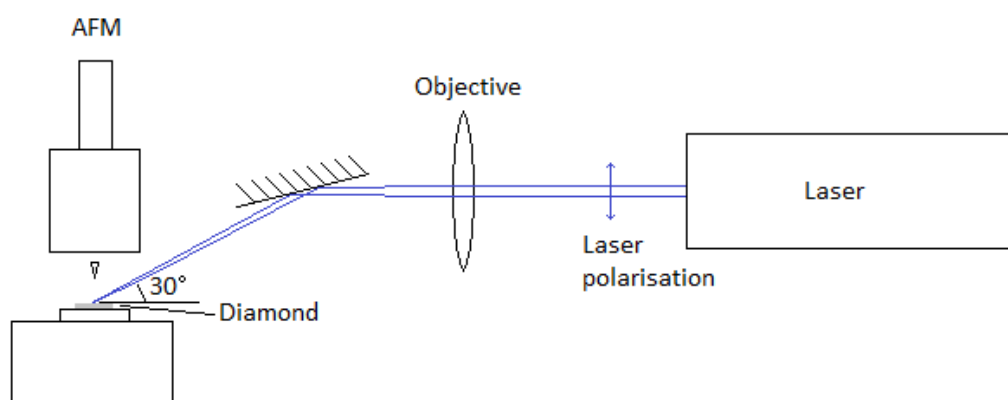
systems built to study surface phenomena of diamond, however problems with access will likely prevent this from eventuating.

Jim Butler Prior to leaving the DC area, we had a very informal meeting with Dr Jim Butler at his home in Virginia. Dr Butler is a prolific researcher in the diamond field, and is an expert on the synthetic growth of diamond. He pointed us towards works involving UV interactions with diamond which may be related to two-photon etching, as well as sharing general advice about working with diamond from a surface science perspective.

Experiments

For our experiments we used a Q-switched 4th harmonic Nd: YAG laser capable of delivering up to 3 watts at 266 nm with a repetition rate of up to 300 kHz and a pulse duration of about 10 ns as the etching laser, and primarily analysed samples using either a Park Systems XE7 AFM or the Supra55VP FESEM at Harvard Centre for Nanoscale Science.

The experiments were fairly straightforward in design. Diamond samples were analysed by SEM3 and AFM, after which they were etched with a variety of laser parameters and exposure times before being analysed again. A line focal geometry was used for earlier experiments (such as with the polycrystalline block structure), simply using a cylindrical lens to focus on a vertically mounted sample. The advantage of this geometry is that the long focus allowed for stripes to be etched onto samples, and the effects of different doses of radiation could be seen by simply moving along the Gaussian profile of the stripe. Later experiments used a spherical focus and directed the beam onto the sample plate of the AFM, as shown in fig.14. This arrangement allowed the AFM's optical microscope and sample translation stages to be used to align and monitor the system, while also allowing exposures to be examined by AFM immediately after their completion. Additionally, this geometry would later be used by my supervisor for tip enhanced etching experiments.



*Figure 1:
Diagram of
Experimental
arrangement for
spherical focus
etching*

Results

The precise methodology of experiments, as well as the outcomes arising from them, was greatly influenced by the availability of samples. As my experiments were destructive in nature, we could only use material which the Loncar group had finished working with, but had not yet been polished down to recycle the substrate. There was some suitable material available, but unfortunately it was sent overseas for additional processing around the time I arrived, and was not returned until the last week of my visit. The first weeks of the visit were spent setting up the etching laser, learning to operate the AFM, and performing etches on whatever other samples I could obtain.

Polycrystalline AR coated sample

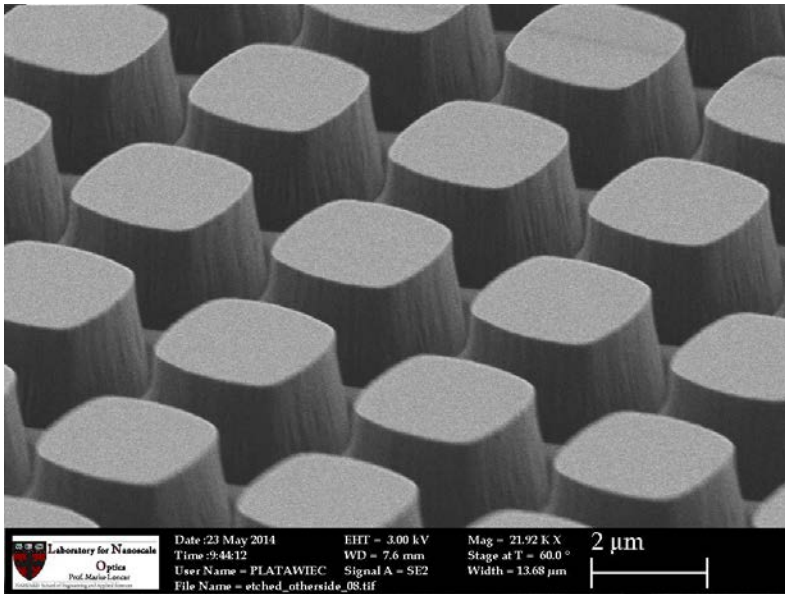


Fig 2 Polycrystalline anti-reflection coated sample. The block-like structures are $3 \times 3 \times 2 \mu\text{m}^3$ (W×L×H) with a $4 \mu\text{m}$ pitch. The very large number of uniform structures allowed comparison between similar blocks (i.e. before/after of a given block was not required). Several long stripes were etched onto the sample with a cylindrical focal geometry. This produced a large number of blocks with the same exposure time, but laser fluence varying as a function of position along the stripe. Image courtesy of Pawel Latawiec.

This sample, shown in fig. 2, was polycrystalline diamond fabricated with a “moth’s eye” anti-reflective coating structure, consisting of a large array of blocks. I was able to obtain this sample early in the visit, and was able to spend a good amount of time working with it.

Figure 3 shows a comparison of a block etched by roughly 200 nm with a nearby unetched block. A significant increase in roughness is clearly seen on both the top and sides. The large section missing from the top of the etched block does not represent a normal surface modification, but seems to be a result of a defect on the original sample.

The top surfaces of etched regions show a typical ridge structure which runs perpendicular to the laser polarisation. It is surprising that there are very well defined ridges over the entire etched region consistent with etching on a well oriented cubic (100) face, despite this sample being polycrystalline. One might expect that grain boundaries would be easily distinguishable by a change in the morphology of the ridge structures, however this is not the case. More experimentation with etching polycrystalline samples is required to assess why this might be.

Looking at the structure of the side walls, it is clear that there is a significant amount of roughening caused by UV exposure. Based on the height of the blocks and the width of the wall as seen from above, the angle of the walls can be calculated as

~ 10°. Fr

that the beam is projected onto an area six times larger on side walls compared to flat surface, as illustrated in fig. 4. This would result in a reduction of intensity per area of diamond by a factor of six, which would therefore produce a 36-fold reduction in etch rate. This does not appear to be the case, as the roughness on side walls seen in fig. 3 (and elsewhere on the sample) is comparable to the roughness on top. Furthermore, the Fresnel reflection coefficients for p and s polarisations on these side walls are 0.14 and 0.73 respectively. The top and bottom side walls would be irradiated with p polarised light, and left and right walls with s polarised light. There is a very large contrast between reflectance at these surfaces, but they are very similar in appearance. This indicates that whether light is reflected or transmitted does not affect the etch rate.

The above observations suggest that during etching, the system should not be thought of in terms of a single large surface into which energy is deposited, but rather as a collection of individual absorbers. This finding is consistent with our existing model in which absorption occurs at the extreme surface (most likely by oxygen termination groups), and strengthens the idea that interaction of the field with the bulk has no bearing on UV etching.



Figure 3: Comparison of two nearby blocks: one unetched (left) and one etched (right). Approximately 200 nm of material has been removed from the block on the right over a 40 minute period. The red arrow indicates the polarisation direction of the etching laser.

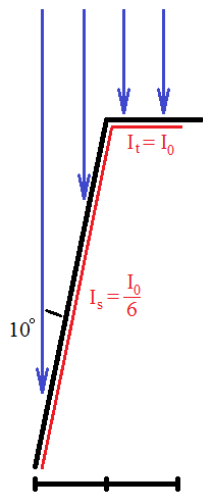


Figure 4: Diagram showing the difference in intensity of a beam projected onto flat (I_t) and angled (I_s) surfaces.

Planar angled etching

These experiments were performed after the etching laser was converted from a cylindrical focussing geometry to the spherical geometry of fig. 1. It served both as an investigation of UV etching at a shallow angle of incidence (which has not been studied before), as well as a test of the effectiveness of the new etching geometry. An unstructured piece of single crystal Type IIA diamond which I brought from Macquarie was used.

Unfortunately the results of these experiments are still somewhat incomplete, as the arrival of the nano-structured samples late in the visit meant that though the planar angled exposures had been performed, there was not enough time to properly analyse them. Some preliminary results were nonetheless interesting.

Figure 5 shows that there were some unusual surface contaminants observed. Before beginning these experiments, the sample was aggressively cleaned by boiling in an aggressive mixture of acids, and should therefore be free of contamination. It should also be noted that after exposing this sample to UV it became badly charged, and the electrostatic forces made it impossible to perform AFM scans without first removing the sample and rinsing it in isopropyl alcohol to dissipate the accumulated charge. It appears that the UV exposure leaves the surface highly charged, and the contaminant in the left image is likely composed of some form of adventitious material in the atmosphere brought to the surface by electrostatic attraction. Whether this charging is a direct result of material removal or simply due to multiphoton photo-emission is

unclear. This result also indicates that if UV etching is used in the processing of delicate structures, a post processing cleaning step may be required. This contamination was not observed in deeper etches, though that may simply be because the roughness of such etches obscured the contamination.

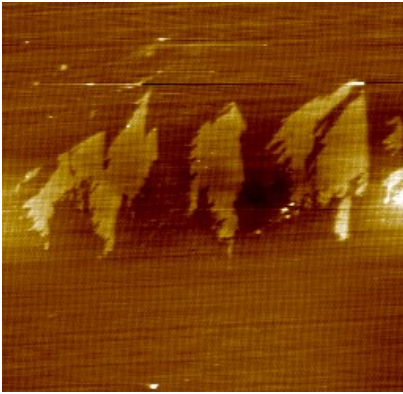


Figure 5: AFM image (contact mode) of an exposure made at 60° to the normal on a planar surface. The image shows a very shallow etch (only a 4 nm deep) which has accumulated a thin film (roughly 3 nm thick) of some unknown contaminant over the location of the beam.

Square Pits

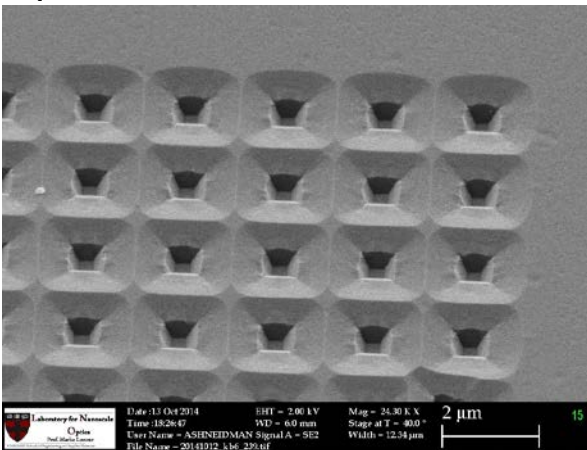


Figure 6: Single crystal structured sample containing large arrays of square pits $0.13 \mu\text{m}^3$ (W×L×H) with a $2 \mu\text{m}$ pitch. As the structures are highly regular, a large number of exposures were performed across the sample with constant laser parameters (selected to produce the greatest depth per second) and varying exposure times. Image courtesy of Anna Shneidman

This sample was one of the nano-structured samples obtained in the last week of the visit, and consisted of large arrays of square pits, shown in fig. 6. Many exposures were performed, ranging from 30 minutes to 30 seconds, all with the same beam parameters (selected for maximum removal rate). Depths were achieved from 20 nm to 500 nm.

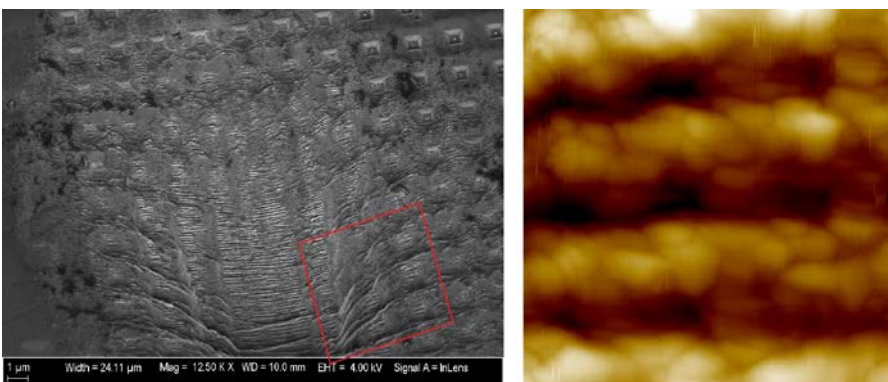


Figure 7: SEM (left) and AFM (right) images of deeply etched (depth 500 nm) square pits. The red square indicates the approximate location of the AFM scan. The SEM image is taken from 30° to the sample Normal.

Figure 7 shows the deepest of these etches. Where significant etching has occurred, the fine details of the square pits have vanished, but rough pits of similar size can still be observed. It appears that the high spatial frequency components of the structure disappear, and are replaced by the high frequency ridge structure. The low spatial frequency components (i.e. the rough shape) are still visible, even after etching five times the depth of the pit.

There is a distinctive ‘wrinkled’ appearance to these etches, as deeply etched lines show a distinctive curve. This is a combination of two factors, shown in fig. 8. Firstly, etching at an angle tends to form a skewed pit, as shown on the left side of fig. 8. Secondly, it appears that edges which face into the beam etch significantly faster than the rest of the sample. This is evident in fig. 7, where the deep ‘wrinkles’ occur along the edges of the pits which face into the beam. Figure 9 shows more examples of this, and this behaviour is also noted on the nano-pillar sample discussed below, on the cylindrical pits which surround the pillars.

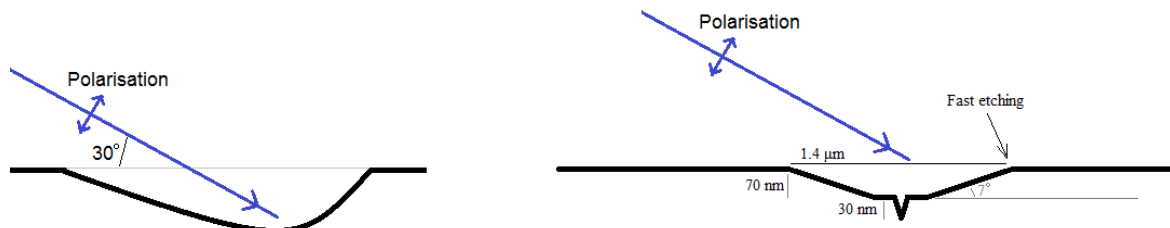


Figure 8: Left: diagram of the skewed shape of an etched pit when the laser is incident at an angle. Right: diagram of the anatomy of the square pits shows the preference for etching faster at edges which face into the beam.

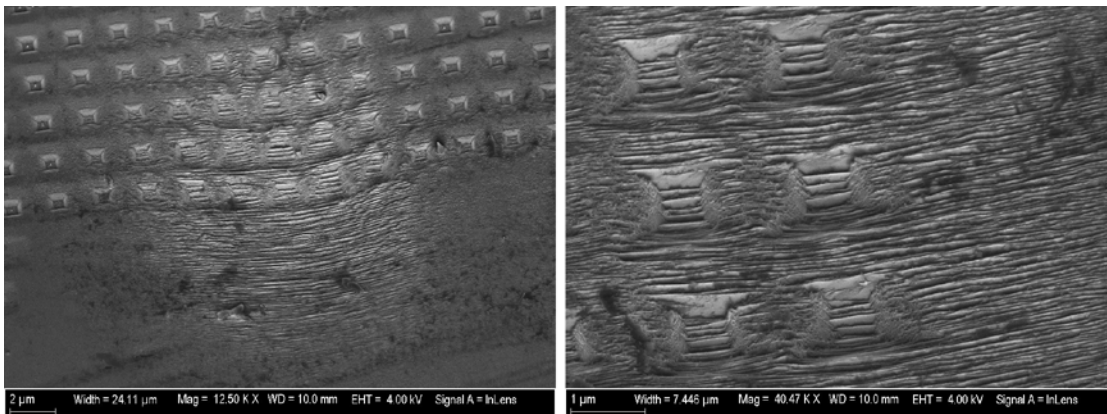


Figure 9: SEM images (viewing angle 30° to the sample normal) of two etch with lower exposure time than fig. 7. Left: the formation of a deep curved trench is seen to align with the edges of pits which face into the beam. Right: a close up of etched pits shows heavier etching on the bottom side.

Nano-pillars

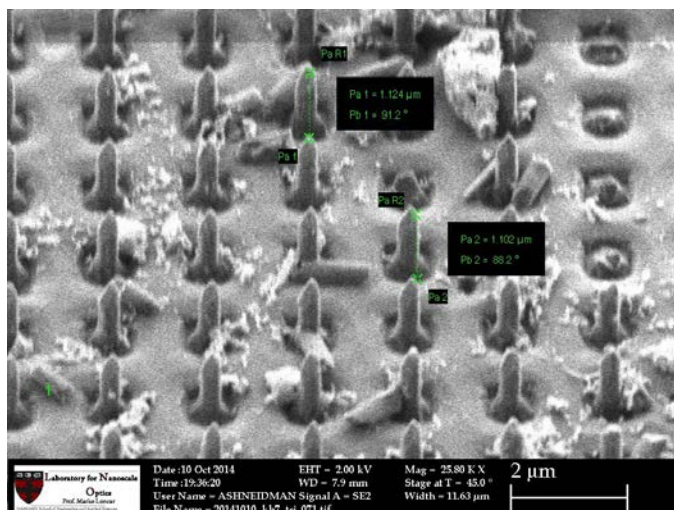


Figure 10: Single crystal nano-pillar sample, showing region with remnants of pillars which have either broken off or failed during fabrication. They are roughly 500 nm wide and on the order of a few hundred nanometres tall. These account for the vast majority of the structures present. Some sites contain the bottoms of pillars, while others are simply empty pits. The remnants are distinct enough on an AFM image to be able to observe changes after etching. They were numerous about the sample, but were inhomogeneous in shape and distribution. As a result, numerous exposures could be performed, but it was necessary to image

the specific area to be etched prior to exposure (i.e. analysis requires before/after images, as opposed to comparing different exposed and unexposed areas). Exposures were performed with laser parameters selected to produce the greatest depth per second, as a function of exposure time. Image courtesy of Anna Shneidman.

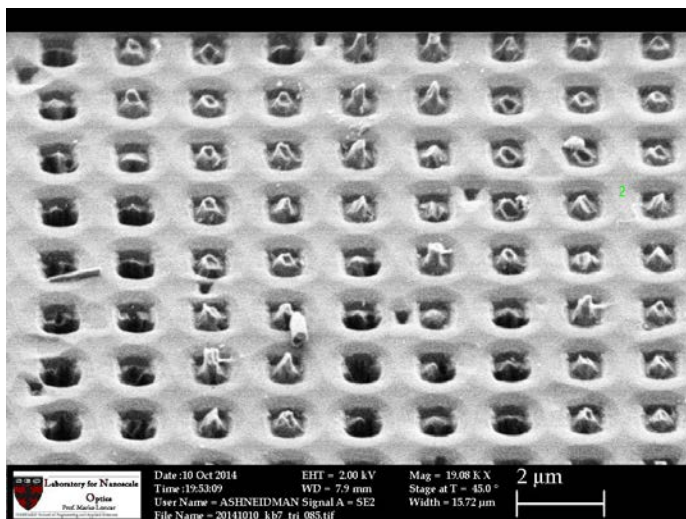


Figure 11: The same sample as shown in fig. 10. Intact pillars, roughly $1.1\ \mu\text{m}$ high and $500\ \text{nm}$ wide. There are very few intact pillars on this sample; they are concentrated in a single area and this image shows roughly half of them. Due to the limited number of available pillars, short exposures were performed successively in a single area, with AFM images being performed between each one. This was performed in two areas containing pillars. The laser fluence was significantly reduced for these exposures in order to reduce the likelihood of ablating the pillars. Image courtesy of Anna Shneidman.

The second sample which arrived in the final week was composed of a large number of broken nano-pillars (fig. 10), with a very limited number of mostly intact pillars concentrated in a single region (fig. 11).

Nano-pillar remnants

Nano-pillar remnants were etched primarily in preparation for experiments with the limited number of intact pillars. Figure 12 shows a comparison of a region of sample before and after exposure. What is most notable here is that pillar remnants are removed in a very binary fashion. For E1 to E4, all remnants in the vicinity of the exposure are completely removed. If this were due purely to UV etching, then moving away from the centre of the focus there would be pillars which were less heavily etched as the intensity decreased. This does not appear to be the case, and there are few examples of pillars which have been altered but not removed.

Only in the case of the shortest exposure (E5) is there evidence of pillar remnants being altered while still surviving. This appears to indicate that the alteration to these pillars is not due to UV etching, but to a more rapid and catastrophic mode of damage. These measurements demonstrated the fragility of these structures, which informed the design of experiments on intact pillars (i.e. lower fluences were used in short bursts).

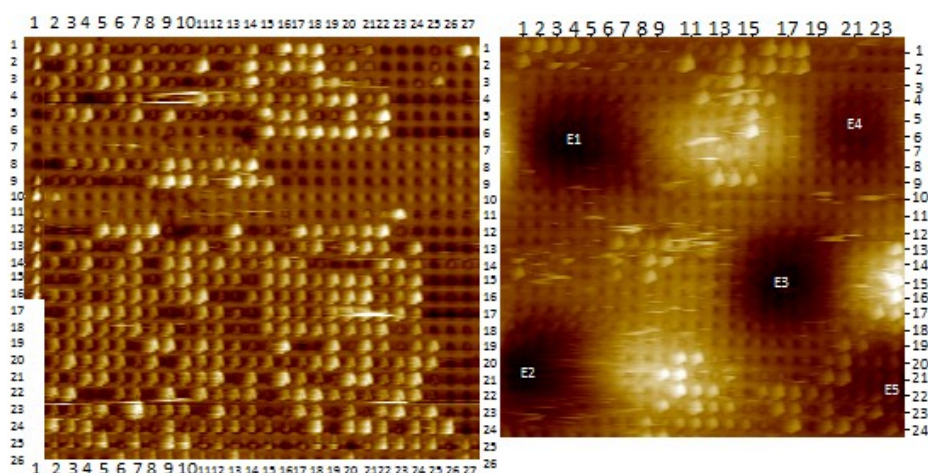


Figure 12: AFM images (contact mode) of nano-pillar remnants before (left) and after (right) etching. Exposure times are E1 = 10 mins, E2 = 15 mins, E3 = 7:30 mins, E4 = 5 mins and E5 = 2:30 mins. All exposures had the same laser parameters, selected to provide the most material removal per second. Rows and columns

are numbered the same for each image to allow easier comparison of a given site. Note that the AFM tip could not image the steep walls of pillar remnants, so the shape produced is a convolution of the shape of the AFM tip and the remnant. Note that the bright sections on the right of exposures are an artefact of the AFM.

Intact nano-pillars

Given that the pillar remnants were so easily destroyed by the UV laser, and there was a very limited number of intact pillars, exposures of intact pillars were done slowly. The repetition rate of the laser was increased from 50 kHz (used in pillar remnant exposures) to 80 kHz, and the total power was decreased, resulting in a reduction in pulse energy by a factor of two. Short exposures were performed, with AFM scans taken immediately after each.

As seen in fig. 14, even under these more gentle conditions, there is a sudden mechanism of removal. After the first minute of exposure there was virtually no change to the structures, but after an additional two minutes there was total removal of many pillars, with some damage to pillars around the edges of the focal spot. While the mechanism of damage here is not as binary as was observed with the pillar remnants, it still seems to come on suddenly.

The pulse energy was reduced again by 45% and the repetition rate increased to 100 kHz, providing an even gentler etch. The results are shown in fig. 15. Here after a single exposure of 1 minute a modification of the pillars was achieved.

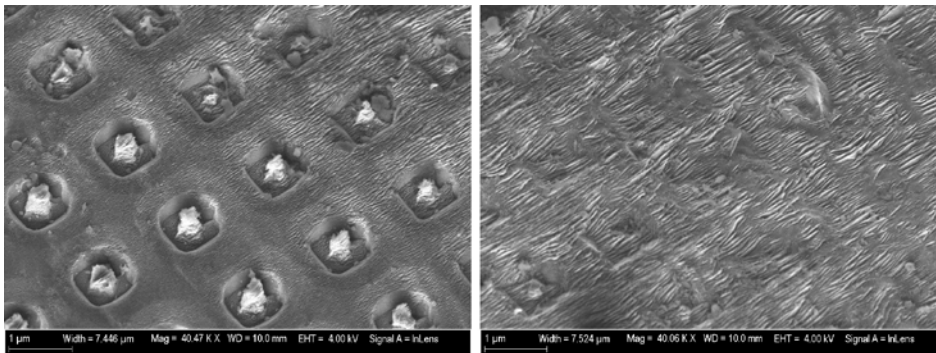


Figure 13: SEM images of etched pillar remnants. Left image: The top right corner is closest to the focus of the laser and is thus most heavily etched. Pillar remnants in the bottom left corner are more or less untouched. It can be seen that when exposed to the laser the remnants are quickly reduced to small conical

structures, before vanishing completely. Right image: bottom of a deeply etched pit, with virtually all traces of pillar remnants removed

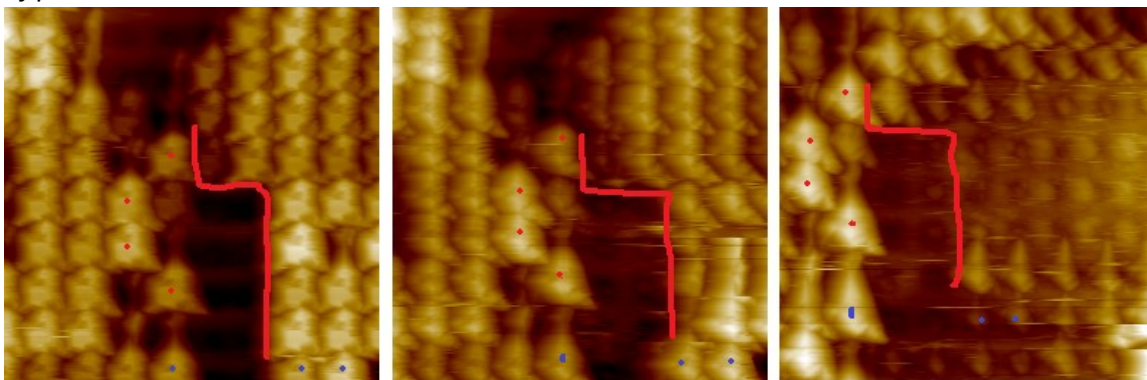


Figure 14: AFM images (contact mode) of nano-pillars before etching (left), after 1 minute etching (middle) and after an additional 2 minutes of etching (right). The removal of pillars on the rightmost image shows the location of the focal spot. Note that the AFM tip could not image the steep walls of pillar remnants, so the shape produced is a convolution of the shape of the AFM tip and the remnant.

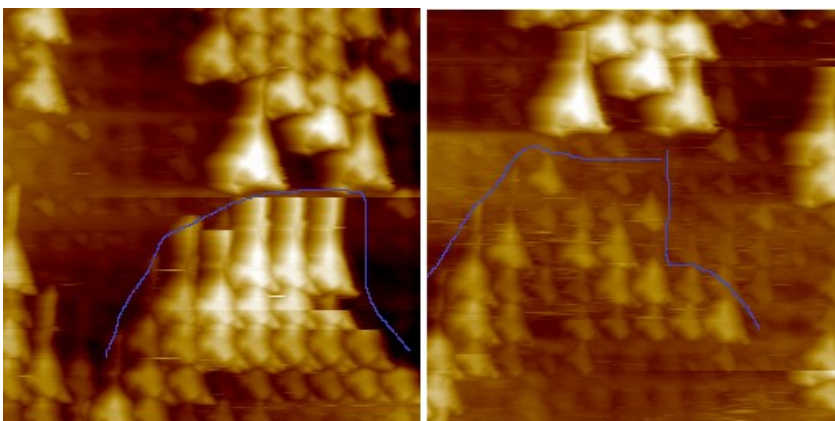


Figure 15: AFM images (contact mode) of nano-pillars before etching (left), after 1 minute etching (right). Note that the AFM tip could not image the steep walls of pillar remnants, so the shape produced is a convolution of the shape of the AFM tip and the remnant.

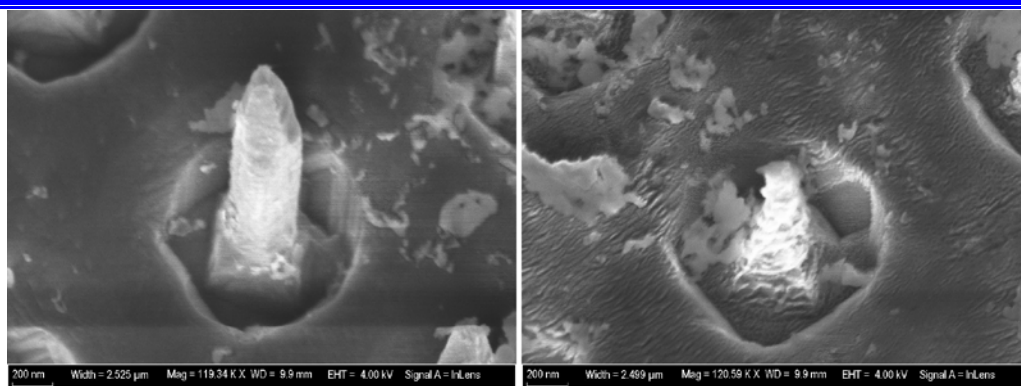


Figure 16: SEM image of single nano-pillars: unetched (left) and after 1 minute of gentle etching (right). Image is tilted 30° from the sample normal

Figure 16 shows a comparison between a typical unprocessed pillar and one which has been modified (from fig. 15). From this it can be seen that the pillar has reduced in size in all directions and become significantly rougher. The amount of material removed from the pillar (the radius has reduced by ~ 100 nm and height by 300 nm) is significantly higher than the amount retched away from surrounding areas.

This fast rate of material removal coupled with the near binary nature of damage seems to indicate that the pillars are being modified by another damage mechanism; possibly laser ablation. As this comparison shows that material is being removed rapidly from all sides, it may be that surface defects left as a result of the RIE processing allow for greater absorption of the UV radiation, effectively lowering the threshold for laser ablation.

There are still problems with this model. It is notable that the rapid material removal only occurs on the pillars, and ceases when the pillar is destroyed, as seen in fig. 13. Laser ablation in the nanosecond regime tends to leave a graphitized layer, which would then cause the surrounding surface to graphitize and ablate due to the increased absorption. Furthermore, there is a lack of obvious redeposited graphite in the SEM data (the detritus visible in fig. 16 appears to have been present prior to exposure).

Conclusions

Despite the late arrival of samples hindering the amount of data which was able to be taken, the results have both deepened understanding of the UV etching process, as well as raised a number of interesting questions to be explored later in my studies. There is interest in the Lončar group in the outcome of these experiments, and several group members have agreed to alert me if any material suitable for my experiments becomes available, and are willing to loan me these pieces at some point in the future. If and when this occurs, I will be able to conduct more experiments in order to better reconcile the findings of this trip, and form a more cohesive picture of the effects of etching nano-structured surfaces.

I feel that this trip has allowed me to grow as a researcher. Through the many researchers I met I built considerably on my network of contacts, and opened avenues to new potential collaborations. It also offered me a new perspective on how research is done. After my time at Harvard, as well as visits to various top level research facilities, I have seen how world leading work is done. I hope to use this perspective to inspire my own work to a new standard.

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Mr Keng Chan from the Australian National University visit to Oslo University for a period of 3 months

Mr Keng Chan from the Australian National University visited the University of Oslo in Norway. The purpose of this report is to briefly summarise an ANN overseas Travel Fellowship visit (Sep 2014 – Nov 2014) to the Centre for Material Science and Nanotechnology as part of an ongoing collaboration with Professor Bengt Svensson and Assoc. Prof. Lasse Vines.

Research Visit Aims

The main aim of this visit is to characterize electrically active deep level traps/defects in ZnO. Electrically active deep traps can act as compensating defects for donors/acceptors. They can produce significant changes in the electrical properties of semiconductors and hence deteriorate device performance. This is especially important for ZnO, which is a promising semiconductor for nano-electronic devices because of its wideband gap, high electron mobility, large exciton binding energy and ease of growth. Despite years of studies, the fabrication of devices based on ZnO nanostructures is still hindered by the difficulty to obtain p-type conductivity.

Due to the difficulty to fabricate high quality Schottky contacts to ZnO, there is still a limited study on electrically active defects in ZnO with junction spectroscopy techniques such as deep level transient spectroscopy (DLTS) and admittance spectroscopy (AS). Schottky contacts are important vehicles/tools to probe electrically active defects in semiconductors with these junction spectroscopy techniques. We managed to fabricate high quality Schottky contacts with rectifying ratio $> 10^3$ in our lab at the Australian National University, particularly after surface pre-treatment with hydrogen peroxide. However, these Schottky contacts suffer from degradation at elevated temperatures in vacuum. Prof. Svensson's group has a DLTS setup that allows high temperature measurement in air. This may prevent the Schottky contacts from being degraded during high temperature scans, thus allowing the detection of defects with energy level deep into the bandgap.

Research Outcomes

DLTS were successfully carried out on as received melt-grown and hydrothermally grown ZnO wafers. However, the Schottky contacts are still found to degrade at elevated temperature despite being measured in air. The result suggests that annealing in vacuum may not be the only reason why the ZnO Schottky contacts degrade during high temperature measurements. The result also indicates that there may be a need to passivate the surfaces of ZnO to prevent them from becoming too conductive during high temperature measurements and operations.

Nevertheless, high temperature DLTS scan in melt grown samples still reveals a surface/subsurface defect with an energy level located at 1.07 eV below the conduction band. From the comparison with previous positron annihilation studies [1], the defect is tentatively attributed to Zn vacancy clusters.

Helium implantation has also been carried out at the University of Oslo in hydrothermally grown samples to investigate irradiation-induced electrically active defects with DLTS. The Helium implantation introduces an additional defect level located at 0.55 eV below the conduction band. This peak is found to be similar to the one observed previously after irradiation [2 -5], and has been tentatively attributed to O vacancies or Zn interstitials.

Research Benefits

The visit to Prof. Bengt Svensson's group has significantly improved my understanding of electrical characterisation of semiconductors. I also have the opportunity to attend a conference on semiconductor interfaces held at the University of Oslo during my visit. This has allowed me to hear talks from several invited top speakers, such as Prof. Leonard Brillson who is a leading scientist in ZnO research. The research outcomes of this trip will also be written as a part of my thesis.

During my visit to University of Oslo, I have made many new friends. They may become my important collaborators in the future. The visit has also allowed me to gained valuable experience of working with a research group based in a foreign institution.

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Mr Phillipp Gutruf from RMIT University visit to the University of Illinois, USA.

Functional Materials and Microsystems Research Group- School of Electrical and Computer Engineering- RMIT University, Melbourne, Australia

As outlined in the application to the travel fellowship, the proposed research visit to America had the following agenda, a research visit at the Bao group, an oral presentation at The MRS 56th Electronic Materials Conference in Santa Barbara and a research visit at the Rogers group which is the leading research group in the field of flexible electronics. I am happy to report that all of these goals have been achieved.

The visit at Stanford University enabled me to gain an overview of the activities of the Bao group, led by Professor Zhenan Bao. During my stay I was fortunate to see all the facilities of the group, present my research and give an overview of the research of the Functional materials and microsystems research group at RMIT. Furthermore I was able to establish an exchange of idea and materials for micro/nano cracked conductors with Alex Chortos, a PhD student working on this topic.

The talk at the MRS 56th Electronic Materials Conference with the title *"Solving the Process Temperature Problem for Flexible Electronics - High Quality Oxide Transfer to Elastomers"* was well received, a high attendance despite the football world cup and early time of the day demonstrated interest on my research. Furthermore the organisers of the conference decided to award me travel support which waves the registration fees for the conference.

Lastly the research visit at the Rogers group led by Professor John Rogers at the University of Illinois fulfilled all expectations. During the 8 weeks stay I was able to gain access to the facilities quickly and immediately start contributing to the paper *"Epidermal Electronics with Advanced Capabilities in Near Field Communication"* which was submitted to *Small*. The paper reports on skin conformal passive Near Field Communication (NFC) devices with a focus on mechanical behaviour of the receiver coil. My contribution was recognised with authorship on the paper. The ANN travel fellowship is acknowledged in the manuscript. Furthermore a new project *"Fingernail NFC electronics with energy harvesting capabilities"* was started and the group comprised of Tony Banks, Jeonghyun Kim and myself were able to fabricate working prototypes which were tested and characterised. The NFC devices where engineered to a very small form factor to fit on a human fingernail which is the substrate for the device. This novel approach allows small form factor wearable electronics. The journal article related to this project is close to submission. Additionally projects such as thermochromic and colorimetric pH epidermal sensors with NFC capabilities where successfully commenced. Functional prototypes where fabricated and await characterisation. Furthermore a project on epidemal Ultra high Frequency devices was commenced and passive id tag devices where fabricated and successfully tested. During the time at the Rogers group, I was fortunate to give multiple talks on my research and received positive feedback from group members, visiting professors and industry representatives.

I thank the Australian Nanotechnology Network for this Overseas Travel Fellowship which has enabled me to undertake this travel to produce high quality research in an internationally highly regarded group, initiate new collaborations and also present and receive feedback on my research outcomes from an international audience.

Mr Roman Lyttleton from the University of New South Wales to visit Lund University, Sweden

Report on 2014 ANN Overseas Travel Fellowship – 6 week visit to Lund University, Sweden by Roman Lyttleton

Visit dates: 5/11/2014 to 18/12/2014

Brief project outline: This research visit contributed to a collaborative project aimed at producing an electrical sensor for detecting filament traffic in chip-based actomyosin molecular motor assays. These consist of myosin proteins bound to the surface (see Fig. 1) with their 'feet' pointing upwards, ready to bind to actin filaments. The myosin motors propel the actin filaments randomly across the surface when adenosine triphosphate is supplied. This motion can be directed by confinement to nanochannels on the surface. By placing a carbon nanotube field-effect-transistor (CNFET) directly in the path of the actin filaments, we aim to electrically detect the passage of actin filaments. The broader goal is to produce an electrical readout to augment optical approaches (e.g., Lard *et al.*, Sci. Rep. 3, 1092 (2013)).

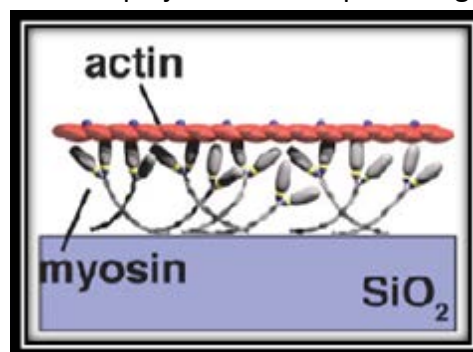


Figure 2: Schematic Diagram of actin/myosin molecular motor system.

Collaborative partners: Prof. Heiner Linke's group at Lund University in Sweden with expertise in creating nanochannels for actomyosin motion control, Prof. Alf Månsson's group at Linnaeus University in Sweden with expertise in controlling actomyosin motion, and A/Prof. Adam Micolich's group at UNSW with expertise in nanoscale electrical devices.

Funding sources: This trip was jointly funded by an Australian Nanotechnology Network Overseas Travel Fellowship and a travel grant from the Solander Program (www.solander.lu.se)

Research Visit Outcomes: My aim for the visit was to: a) learn aspects of nanochannel design, fabrication for actomyosin assays and how to combine it with a CNFET device; b) work on creating an electrical measurement system that simultaneously conforms to the inverted 'sample-in-liquid' fluorescence microscopy set-up used in actomyosin assays while learning the required fluorescence microscopy skills; and c) if time allowed, perform initial studies of CNFET operation in this environment.

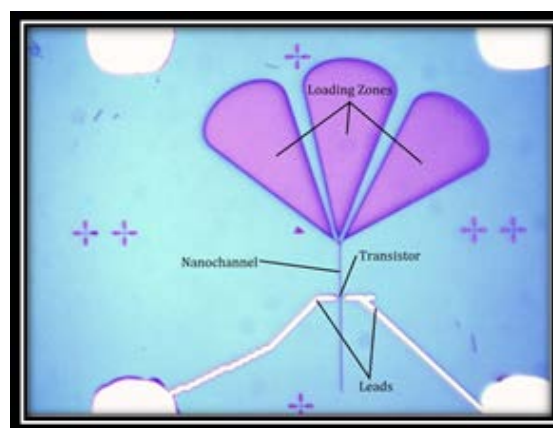


Figure 3: Optical photo of nanochannels & loading zones (purple) created in PMMA(blue) aligned with a CNFET in between leads (white).

I spent 6 weeks working in Lund, focussing mostly on aspects a) and b) above, working closely with Prof. Linke's Ph.D. students, Mercy Lard and Frida Lindberg. A key outcome on the device fabrication side was the development of processes in the Lund Nanolab for producing actomyosin nanochannels precisely aligned perpendicular to CNFET devices that I made at UNSW (see Fig. 2). This joining of fabrication capabilities at UNSW and Lund will be vital to getting this experiment to work and we are currently optimising our CNFETs ahead of making final devices for this experiment.

The key outcome on the interfacing side was the development and initial testing of an electrical set-up for low noise measurements (see Fig. 3) of devices incorporated into the glass-slide flow-cells used in chip-based actomyosin studies. The primary difficulty here is that the device needs to be operated in a liquid buffer solution. Care is needed to prevent short-circuits and minimise drift and noise due to the electrolyte. This required several iterations of glass-flow cell development to overcome unexpected issues with buffer leakage, sample packaging and microscope access.

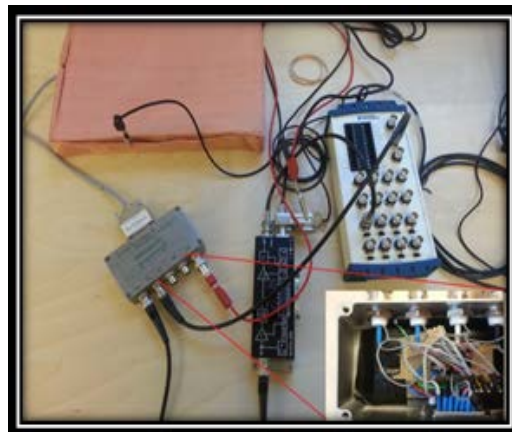


Figure 3: Electrical systems required for low noise measurements.

Much of this had to be done 'on the fly' exploiting what we could get our hands on at short notice, and we are now refining our approach to this towards the device structures needed to complete this ambitious experiment.

Ultimately, the visit provided a great opportunity to expand my device fabrication skills at one of Europe's top nanotechnology institutes, and learn aspects of fluorescence microscopy and flow-cell design for actomyosin studies that are vital to my Ph.D. research. The visit also enabled us to make significant progress towards our goal of achieving electrical detection of actin filament traffic in actomyosin assays.

Mr Tushar Kumeira from the University of Adelaide visit to the University of California, USA.

Report submitted in fulfilment of the requirement of the Overseas Travel Fellowship submitted by Tushar Kumeria, PhD Scholar at the School of Chemical Engineering, Faculty of Engineering, Computer, and Mathematical Sciences

Introduction

There is a growing need for sensors that can monitor the residual adsorption capacity of activated carbon filtration cartridges in air purifying respirators and other personal and collective protective equipment. End of service life indicators (ESLI) generally operate by detecting chemical vapors as they break through the adsorbent filter bed.



Detection of residual service life (RSL) is more difficult, generally requiring the embedding of sensors within the filter bed or detection of chemical breakthrough at concentrations well below the levels that are Immediately Dangerous to Life or Health (IDLH). For both these applications, size, reliability, and sensitivity are at a premium. Despite advancements in sensor technologies, the need persists for a very small, low-power, and cost-effective sensor. In the United States, NIOSH and OSHA health and safety regulations require the detection of VOCs prior to depletion of the carbon beds adsorption capacity, yet these regulations have not yet been enforced due to a lack of suitable sensing devices.

The industry sectors and cross-sectors being addressed by this project include the chemical industry, painting industry, first responders, petroleum industry, and other industries where occupational diseases caused by breathing air contaminated with harmful dusts, fogs, fumes, mists, gases, smokes, sprays, or vapors are a concern and where acceptable engineering control measures (such as enclosure or confinement of the operation, general and local ventilation, and substitution of less toxic materials) are not feasible.

The goals of this project are to harness our expertise in chemistry, materials science, fabrication, and analytical methods to produce a microsensor prototype that can determine the VOC saturation level and residual life of activated charcoal filters. The process of fabrication of pSi based sensing chip is depicted in Figure 1. Our group has pioneered the use of porous Si in chemical and biological sensing applications. Porous Si has a microporous structure that can be tuned either physically or chemically to express sensitivity to specific analytes. The absorption of molecules inside the pores causes a change in refractive index that can be translated into a shift in wavelength of the peak reflectance spectrum of a photonic nanostructure. Thus the detection event is translated into a color change.

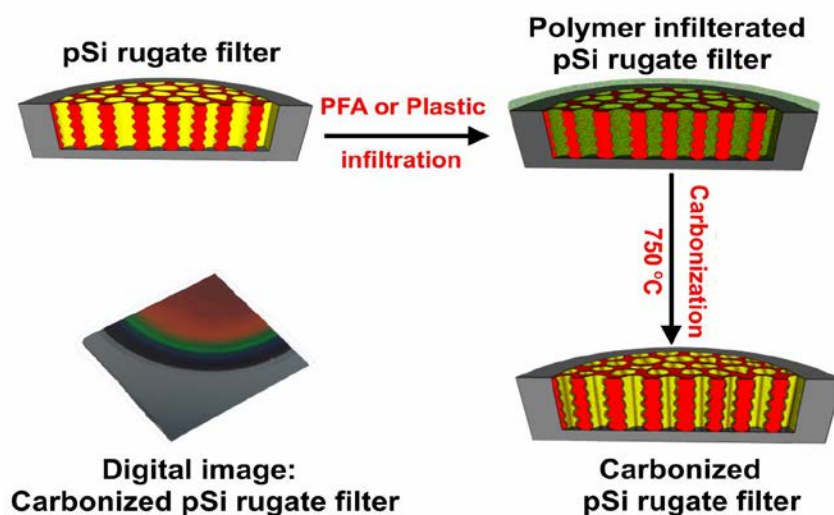


Figure 1: Schematic of pSi rugate filter based VOC detection chip fabrication along with a digital image of the actual sample.

The high surface area and optical interferometric means of detection lead to very high sensitivity for this system. We took this powerful sensing ability a step further in an application as a residual life indicator, by adding the surface chemistry to mimic the adsorbent properties of a carbon bed. It has been found that the carbonization chemistry described above can enhance the absorption properties of the porous photonic crystal by an order of magnitude, the key innovation here is that the sensor precisely mimics the behavior of the carbon adsorbent bed; when placed inside the carbon bed, can provide an accurate, real-time assessment of the status of the adsorbent for ESLI and RSLI applications.

Proposed Goals

1. Overall goal and aims

The overall goal of this project is to explore the fundamental materials science, chemistry, and optical physics enabling small, cost-effective optical sensors to monitor the residual adsorption capacity of activated carbon filtration cartridges in the powered air purifying respirators and other personal protective equipment. The proposed work will consist of three specific aims:

Aim (1): Fabrication and design of porous silicon photonic crystal,

To design and fabricate porous silicon photonic crystal sensor elements known as rugate filters. These photonic structures display a sharp and narrow stop band in the reflection spectrum. Notice that, the position of the stop band of these pSi rugate filter photonic structures in the reflection spectrum can be manipulated and tuned *ad libitum* for specific applications. Furthermore, the position of the stop band is highly dependent on the effective refractive index of the structure, which, in turn depends on the medium filling the pSi pores. This means, filling the pores with a higher refractive index solvent/solution results in shifting of the stop band, which is reversible and stop band shifts back to its original position on removal of the medium filling the pores. This feature of pSi rugate filter makes them attractive for sensing applications.

Aim (2): Surface chemical treatments that yield a high surface-area and carbonaceous surface mimicking activated carbon.

For this, the surface of pSi photonic structures can be modified or carbonized using carbon based polymers preferably poly furfuryl alcohol (PFA) or waste plastic bags as a precursor. Carbonization process not only results in generation of micro-pores inside the meso-pores of pSi photonic crystal but also mimics the properties of activated carbon present in PAPR.

Aim (3): Sensing performance of the carbonized pSi photonic structures.

Sensing performance can be studied using by monitoring the shift in the stop band peak for the rugate filters. Additionally, pSi based can be packed in the flow cell for real-time detection of adsorption of analyte of interest. We will quantify the response of the modified photonic crystals to act as sensors for low volatility chemicals, focusing on maximizing optical response and minimizing interference from the coupling chemistries on the sensor performance.

Goals Achieved

1): Porous silicon rugate filters were successfully fabricated by chemically etching highly doped (P++ type, Boron Doped) Si wafer under galvanostatic conditions. For this a sinusoidal current density waveform was etched into the Si wafer using 3:1 solution of Hydrofluoric acid to ethanol (HF:EtOH). The minimum and maximum current densities were 10 and 120 mA/cm², respectively, with a 5.5 sec period of sin wave and 150 repeats. The obtained pSi rugate filter displays a narrow and sharp stop band at 600 nm in reflection spectrum with close to 59 % porosity. The etching profile, cross-section SEM image and reflection spectrum of the corresponding pSi rugate filter is provided in **Figure 2**.

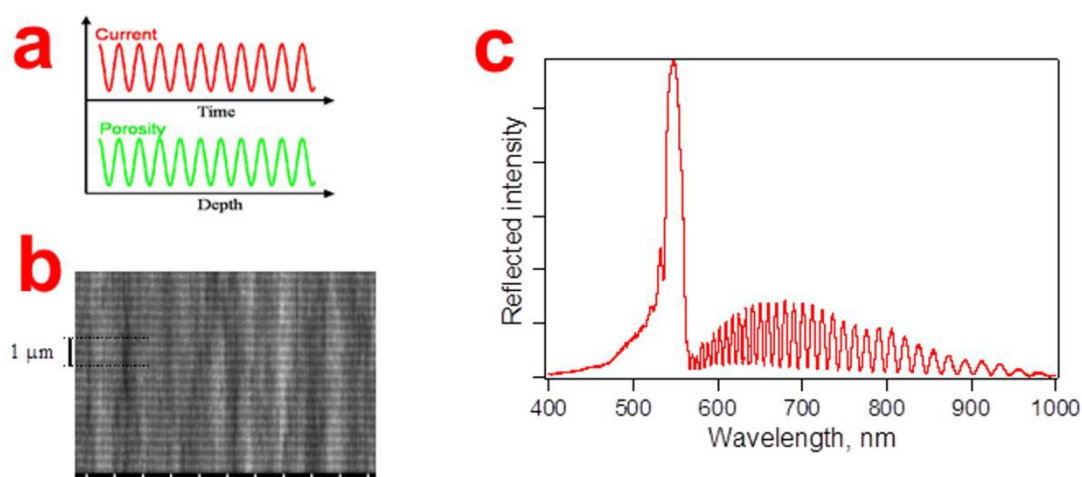


Figure 2: a) Sinusoidal current profile used to etch out a rugate filter photonic crystal of porous silicon. b) SEM image of the corresponding pSi rugate filter. c) Reflection spectrum of the pSi rugate filter etched using the current profile provided in (a).

2): The prepared pSi rugate filters were then carbonized using PFA and waste plastic bags as precursor. For this, pSi rugate filters were first oxidized under ozone environment for 30 min. Then, the oxidized pSi rugate filters were spin coated with 20 % solution of PFA (3 times) at 2000 rpm for 30 sec. In case of using waste plastic bags as precursor, a piece of LDPE (low density polyethylene) bag weighing 60 mg was melt casted onto pSi rugate filter followed by compression under 1 Newton force. The carbon precursor impregnated pSi samples were then inserted into a tubular furnace enabled with provision to create inert environment by flowing nitrogen gas. The temperature on the tubular furnace was increased to 750°C at a rate of 10°C/min. The peak temperature of the process (i.e. 750°C) was maintained for 30 min and subsequently the furnace was allowed to cool down to room temperature naturally. Successful carbonization was confirmed by FTIR spectroscopy (figure 3).

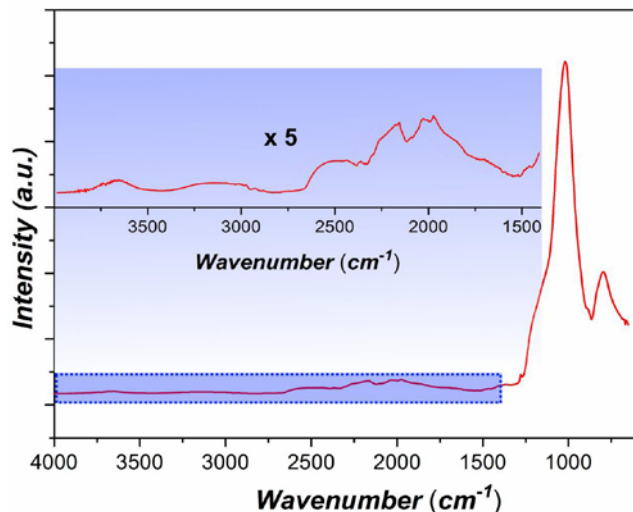


Figure 3: FTIR spectrum for carbonized pSi rugate filter chip.

3): The sensing performance of the carbonized pSi rugate filters was established by monitoring the shift in the reflection stop band as a function of toluene vapor concentration on it. For this, the carbonized pSi samples were packed in Teflon® flow cell with a glass window for obtaining the optical signal and an input (connected to toluene source) and an output (venting toluene vapors to outside fumehood) port. Note that, five different concentrations of toluene (70 ppm to 430 ppm) were introduced onto sample surface to obtain a dose response curve. The real time toluene monitoring curve and dose response for different concentration of toluene is provided in Figure 4. The performance of carbonized pSi rugate filters was compared with non-carbonized pSi rugate filters treated under same conditions (i.e. heating at 750°C under N₂ ambient for 30 min).

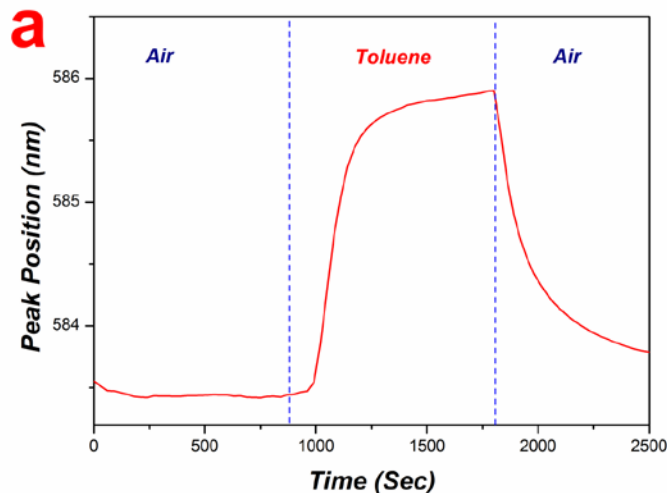
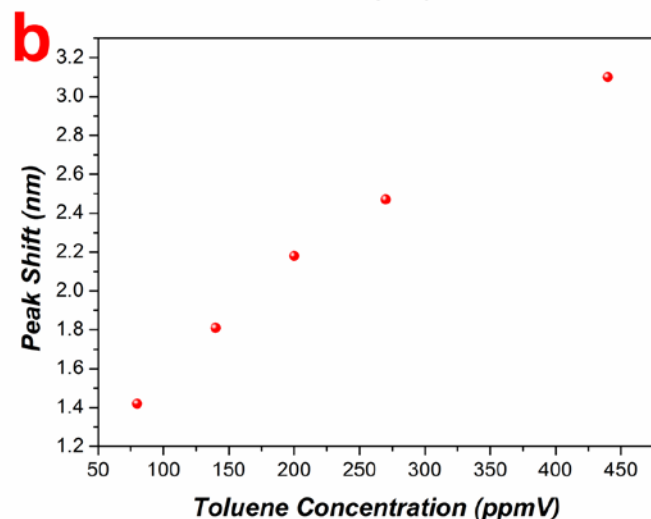


Figure 4: a) Real-time response curve of carbonized pSi rugate filter for detection of toluene.



b) Dose response curve of carbonized pSi rugate filters for detection of toluene at different concentrations.

Summary Table

Month	Subtask
1-2	Designing and fabrication of porous silicon rugate filters with peak between 550-600 nm in reflection spectrum.
3	Carbonization of pSi rugate filters and their characterization
4	Monitoring sensing performance of the carbonized pSi rugate for toluene
4.5	Fabricating porous silicon microparticles composite based on size exclusion(Extra work)

Achievements:

This research stay was a great learning experience and accounts for accumulation of data for two peer review journal publications (under preparation) and one conference presentation as listed below.

Presentations and Publications:

Conference presentation

1. J. Wang, **T. Kumeria**, A. Santos, D. Losic, M. J. Sailor "Encapsulation of Layered Porous Silicon Photonic Crystals in Polymers by Size Exclusion" Silicon containing polymers and composites 2014, San Diego, California, USA Dec 2014. **(Best poster award)**

Journal Publications

1. T. Kumeria, J. S. Gofus, A. Santos, D. Losic, M. J. Sailor "Carbonized porous silicon photonic crystals for vapor sensing" ACS Applied Materials and Interfaces, 2014 (Under preparation)
2. T. Kumeria, J. Wang, A. Santos, D. Losic, M. J. Sailor "Size exclusion based porous silicon microparticle and polymer composite for artificial pigments" Langmuir, 2014 (Under preparation)

Miss Katie Chong from the Australian National University visit to Sandia National Laboratories, New Mexico, USA.

Katie Chong Recipient of the 2014 ANN overseas travel fellowship
PhD candidate at the Nonlinear Physics Centre, Research School of Physics and Engineering,
Australian National University

Fabrication of Silicon Huygens' Metasurfaces for Wavefront Control at the Center for Integrated Nanotechnologies

Metasurfaces have been a hot topic in recent years [1-4], especially in the optical region of the electromagnetic spectrum because of their potential applications in integrated optics and mid-infrared photonics [5,6]. A metasurface is the two dimensional counterpart of a metamaterial; an artificially engineered material made up of meta- atoms which exhibit unusual optical properties not attainable with natural materials, such as negative Refraction and cloaking[7]. The principle idea behind a metasurfaces is to engineer a surface to apply abrupt localized phase shifts to incident wavefronts. Hence we can control the wavefront of the incident light and achieve beam steering or beam shaping without using traditional bulk optics.

A Huygens' metasurface is a metasurface in which the meta atoms act as Huygens' sources [8], i.e. overlapping electric and magnetic dipole sources which are able to produce unidirectional scattering in the forward direction [9]. The fact that a Huygens' metasurface can eliminate the radiation loss in the backward direction offers new unique opportunities for more efficient metasurfaces. The recent research activities in Huygens' metasurfaces have been focusing on using metallic elements in the RF, microwave and optical frequencies [5, 10-12]. Although metallic materials have been a great building block for these Huygens' metasurfaces at lower frequencies, they suffer from significant dissipative losses at the optical frequencies, making them difficult to be used in real world applications.

One way to overcome the problem is to replace the lossy metallic materials with dielectric materials, which are transparent to optical light. For example, it has been shown that silicon disks of a carefully chosen aspect ratio are able to act as Huygens' sources, where the electric and magnetic dipole resonances overlap, producing highly efficient and unidirectional forward scattering at near-infrared frequencies [13].

At the Nonlinear Physics Centre at the Australian National University, Dr Manuel Decker and Dr Isabelle Staude have proposed and experimentally shown that an all-dielectric Huygens' metasurface is able to achieve close to unity transmittance with a 2π phase shift on resonance [14]. Here, we note that the 2π phase shift is required for effective wavefront control. Taking this further, we aimed to use these exciting results to create a functional device – a silicon Huygens' metasurface beam shaper.

During the period between 31st August and 14th October 2013, I visited the Centre for Integrated Nanotechnologies (CINT), Sandia National Laboratories in Albuquerque, U.S.A. to work on the fabrication of such a silicon Huygens' metasurface beam shaper in collaboration with CINT scientist Dr Igal Brener and his group. The beam shaper was designed prior to the visit and was optimized to turn a Gaussian beam into a vortex beam at around the telecom wavelength region. Figure 1

shows the scanning electron micrograph (SEM) of a fabricated sample - our design consists of silicon nanodisks arranged in four arrays which create a $\pi/2$ phase shift difference between adjacent quadrants and a total of 2π phase difference in the whole structure for an incident laser beam.

The sample was fabricated using electron beam lithography on a silicon-on-insulator (SOI) wafer with 250 nm top silicon layer, followed by a reactive ion etching process. The sample then underwent low pressure chemical vapour deposition (LPCVD) of 500 nm of silica.

An optical interferometer and a transmittance setup were built during my visit to characterize the sample. The interferometer was used to measure the spatially varying phase of the vortex beam generated by the sample while the transmittance setup measured the transmittance of the sample in the near-infrared region.

Two working samples with slightly different parameters were fabricated during my visit, and more are being fabricated at CINT which will be sent to me. On my return to Australia, I had built a similar interferometer to further characterize the samples.

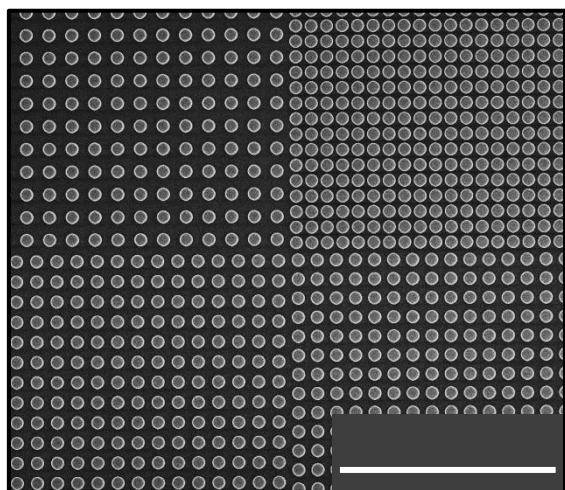


Fig. 1: The scanning electron micrograph of a typical fabricated beam shaper sample. Arrays of silicon nanodisks form four quadrants of the beam shaper where each quadrant produces a $\pi/2$ phase shift increase with respect to the adjacent quadrants.

Preliminary results have shown that our beam shapers work as expected. Publishing these results in a medium to high impact journal is next on our agenda. These results, once published, will also be presented at various international conferences, such as CLEO, META, Metamaterial, etc. and the next ANZCOP conference.

This visit has been very valuable for me. Not only have I obtained the foundational results for my PhD project, I have learnt various nano-processing and clean room procedures, such as wafer polishing and dicing, and low vapour chemical deposition. The access to the unique facilities allowed me to see what is available outside the ANU and the different ways to do things. It has also widened my views on what research centres could be like as CINT is neither a university nor an industry research group which I am more familiar with.

One of the important parts of this visit is the meeting of world class scientists at CINT and also at the 6th international Workshop on Electromagnetic Metamaterial at Santa Fe on the 22nd and 23rd September. At this workshop, I was invited to present a poster on my previous work on the "Observation of Fano Resonances in All-Dielectric Nanoparticle Oligomers" [15]; also a collaborative work with Dr Brener's group. This visit has helped me build an international scientific network which I would have never considered possible before commencing my PhD programme.

All in all, this visit was a great experience for me and it was a successful and productive visit. We envisage that, with the CMOS compatibility of silicon, our Huygens' metasurfaces beam shapers and other nanodevices using the same principle will be integrated on chips for the next generation nanophotonic devices.

I would like to acknowledge the funding support from the ANU Vice Chancellor's HDR travel grant, the Australian Nanotechnology Network (ANN) travel fellowship, Nonlinear Physics Centre at ANU and CINT.

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- [12] C. Pfeiffer, *et al.* Nano Lett. **14**, 2497 (2014)
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- [15] K. E. Chong, *et al.* Small, **10**, 1985 (2014)

Mr Steven Harris Wibowo from the University of Melbourne to visit IBM Almaden Research Centre, California, USA for a period of seven months.

Steven will be travelling to the USA in January to May 2015

Mr Majid Mortazavi from Monash University to visit the University of Pennsylvania, USA for a period of three months.

Majid will be travelling to the USA in July to September 2015

Dr Anthony Chesman from CSIRO to visit Columbia University, USA for a period of twelve weeks

Anthony will be travelling in Jan to March 2015

Mr Fenlong Wang from the University of New South Wales to visit the Max Plank Institute for Polymer Institute, Germany for a period of one month

Fenlong will be travelling to Germany in March 2015

WORKSHOPS, CONFERENCES AND EVENTS

WORKSHOPS, CONFERENCES AND EVENTS

The purpose of the workshops, Conferences and Events is to take stock of the status of the field nationally and internationally, identify emerging areas of research and exchange information and to identify opportunities for collaboration and training. A Large number of ECRs and students have been supported to attend these events.

Advanced Nanomaterials Workshop held on the 30-31st January 2014 at the University of Melbourne

Advanced Nanomaterials for Energy Workshop – University of Melbourne January 30-31, 2014.

In January a satellite meeting to ICONN2014 was held at the University of Melbourne. The purpose of this meeting was to provide researchers in nanomaterials an overview of the different nanotechnologies being applied to solar energy conversion and energy storage. It provided an introduction to some novel materials such as graphene physics, as well as new concepts such as hybrid cells. While most of the focus was on photovoltaics, there was also discussion ranging from hard core solid state theory to experiments in nanoassembly and phase change materials.

The Workshop was opened by Dr Eric Isaacs, Director of the Argonne National Laboratory in Chicago. Argonne has enormous programs into all aspects of energy harvesting and storage. Dr Isaacs visited the synchrotron and the MCN as part of a fact finding mission to examine possible collaborations with Australia on “Nanotechnologies for Energy Solutions”.

On Thursday evening Dr Isaacs held a Public Lecture at the “Spot” attended by over 400 people on the topic: “Energy Future: the Developments in Materials to meet Alternative Energy Challenges”. This was followed by a Panel discussion featuring the Academy of Science President Elect Andrew Holmes, the Grattan Institute’s Gavin Wood and the Greens MP Adam Bandt.

On Friday 31st the workshop proper got underway with a variety of experts from across Australia including: Eric Isaacs “Materials Science in the National Interest”, Peter Littlewood (also Argonne National Lab) “Energy Storage from First Principles”; Klaus Weber (ANU) on “Silicon based PV systems and Sliver Technology”, Buohua Jia (Swinburne University) on “Nanophotonic Solar Cells”. There was then a switch to new materials with presentations by David Jones (University of Melbourne) “Excitonic Bulk Heterojunction Organic Solar Cells”, Paul Dastoor (University of Newcastle) on “Solar Paint” and Udo Bach (Monash University) on “Sensitized Mesoscopic Solar Cells”. The final session included Jacek Jasieniak (CSIRO) on “Solution-Processed Nanocrystal Solar Cells”, Michael Fuhrer (Monash University) on “Graphene Optoelectronics and the Ultimate Transparent Conductor”, Michael Giersig (Frei University, Berlin) “Metallic Nanostructures for Transparent and Conductive Electrodes” and Andreas Fery (Bayreuth University) on “Tailoring Plasmonic Absorption by Self-Assembly”.

The meeting was attended by more than 100 academics, ECRs and students from across Melbourne as well as scientists from CSIRO, University of Sydney, Erlangen Germany, NewSpec Instruments. The workshop was funded by the Victorian Government, the Melbourne Materials Institute, Realtek, AUSIAPV, the Melbourne Centre for Nanofabrication, CSIRO and the Australian Nanotechnology Network. Particular thanks go to Gaby Bright and Noel Dunlop who organised the workshop.

Paul Mulvaney
Workshop Presenter.

List of students covered by ANN funding

Benesperi	Iacopo	Monash University
Bhargava	Rishabh	Monash University
Collins	Sean	University of Melbourne
Dkhissi	Yasmina	University of Melbourne
Edmonds	Mark	Monash University
Gujral	Satnam	Monash University
He	Jiangjing	Monash University
Hellerstedt	Jack	Monash University
Jaber	Sarah	University of Melbourne
Kirkwood	Nicholas	University of Melbourne
Li	Wei	CSIRO
Lloyd	Julian	Monash University
Mapperson	Tim	University of Melbourne
Meyer	Steffen	Monash University
Mortazavi	Majid	Monash University
Moshref Javadi	Mahdi	Monash University
Ng	Soon Hock	Monash University
Nguyen	Thanh	University of Melbourne
Piracha	Afaq	University of Melbourne
Thai	Thibaut	Monash University
Varga	Joseph	University of Melbourne
Zheng	Changxi	Monash University
Widnersson	Ida	University of Melbourne
Saboochi	Solmaz	University of South Australia
Alsaif	Manal	RMIT
Dubey	Pawan	University of Melbourne
Muhammad	Kalim	Monash University
Banal	James	University of Melbourne
Zhou	Yecheng	University of Melbourne
Suvorova	Olga	University of Melbourne
Cousland	Geoff	University of Sydney

5th International NanoMedicine Conference held at Coogee Beach in Sydney on the 30th June-2nd July 2014

The Australian Centre for NanoMedicine (ACN), based at the UNSW was successful in attaining a grant of \$6000 from the Australian Nanotechnology Network (ANN) towards the 5th *International NanoMedicine Conference*, held between June 30 and July 2 2014 at the Crowne Plaza Hotel Coogee Beach Sydney



ACN was officially established as a research centre at UNSW on 20th July 2011 under the co-directorship of Professor Tom Davis (resigned), Professor Justin Gooding and Professor Maria Kavallaris. ACN is a multi-disciplinary research centre incorporating researchers from UNSW's Faculties of Engineering, Science and Medicine. ACN has two key aims, first and foremost as a research centre dedicated to finding solutions to provide a better way of life for those in our population afflicted with hard to treat diseases; and second to work with a diversity of stakeholder groups to communicate research findings and be an Australian hub for nanomedicine discussion and commentary.

Both of these aims are central to ACN hosting the 5th *International NanoMedicine Conference*. 220 attendees representing 22 countries attended the conference. Plenary

speakers during the three day event included

- **Professor Mark E Davis:** Warren and Katharine Schlinger Professor of Chemical Engineering, California Institute of Technology (USA)
- **Professor Shana Kelley:** University of Toronto (Canada)
- **Professor Jason S Lewis:** Vice Chair of Research in Radiology, Chief Attending of the Radiochemistry & Imaging Sciences Service and Director of the Radiochemistry & Molecular Imaging Probe Core at Memorial Sloan-Kettering Cancer Center (USA).
- **Professor Tanya Monro:** ARC Georgina Sweet Laureate Fellow and Director of the Institute for Photonics and Advanced Sensing, The University of Adelaide (Australia)
- **Professor Andrew Whittaker:** Group Leader, Australian Institute for Bioengineering and Nanotechnology and the Centre for Advanced Imaging, The University of Queensland (Australia)

The five plenary speakers were joined by a further 46 invited speakers. The conference also saw a further 53 oral presentations and 43 posters.

Themes of the conference included:

- Drug Delivery
- Bioactive Materials
- Diagnostic / Imaging
- Translational Commercial

- Bio Translational
- Nanoparticles and Nanotoxicology
- Polymer conjugates
- Therapeutic Applications

For the fifth consecutive year it was ACNs pleasure to bring together the top minds in a discipline that crosses boards incorporating medicine, chemistry, and engineering and truly represents the adage of “bench to bedside”, but just as importantly “bedside to bench”.

Through the funding provided by ANN, ACN was able to provide assistance to the following ECRs and PhDs. As can be seen from the list below, funding was provided to assist 17 people representing four institutions.

Nicolas	Alcaraz	Poster	Monash University	<i>Magnetically Responsive Liquid Crystalline Nanostructures for On-Demand Drug Delivery</i>
Stephen	Goodall	Oral	AIBN University of Queensland	<i>Self-assembly of an EGFR-targeting immunomicelle from a thermoresponsive scFv-polymer conjugate</i>
Tushar	Kumeria	Poster	University of Adelaide	<i>Nanoporous anodic alumina micro-particles as a new carrier for localized delivery of anticancer therapeutics</i>
Manpreet	Bariana	Poster	University of Adelaide	<i>Protein-eluting Titania Nanotube-based Implants for Craniosynostosis Therapy</i>
Ye	Wang	Oral	University of Adelaide	<i>Electrochemically Synthesized Anodic Alumina Nanotubes as Novel Drug Carriers for Cancer Therapy: A Toxicity Study</i>
Joshua	Glass	N/A	The University of Melbourne	
Tess	Reynolds	Poster	Institute for Photonics and Advanced Sensing , University of Adelaide	<i>Multiplexed Biosensing Using Whispering Gallery Modes in Complex Media</i>
Rajneesh	Chaudhary	Oral	Deakin University	<i>Engineered zinc ferrite nanoparticulate contrast agent for magnetic resonance imaging of atherosclerosis</i>

Nihal	Maremanda	Oral	Deakin University	<i>Reusable microfluidic devices for capture of circulating tumor cells on aptamer functionalized surfaces</i>
Narinderbir	Singh	Oral	Deakin University	<i>Targeting apoptosis in glioblastoma by employing nano SurR9-C84A</i>
Bhasker	Sriramoju	Oral	Deakin University	<i>The survivin mutant nanocarrier as a novel neuroprotective molecule against Alzheimer's associated toxicity</i>
Pavan	Sunkireddy	Oral	Deakin University	<i>Ultra-small chitosan nanoparticles as novel ocular drug delivery systems: biodistribution and cytotoxicity studies</i>
Kuldeep	Kumar	Poster	Deakin University	<i>Nanoherb formulations for osteoarthritis</i>

An additional \$1000 was sought from ANN for a translational commercial nanomedicine session.

This was undertaken with three of the five speakers in this session, showcasing research application with commercial application. These speakers showcased the journey from their "bench" discovery to commercialisation.

A fourth speaker in this session from the venture capital sector showcased his journey with two of the research companies and how this journey resulted in commercial benefits.

The fifth and final speaker in this session provided information on the government funding opportunities available for establishment of research commercialisation.

The program was structured as follows:

1. **Dr Peter French**, Benitec Biopharma Ltd (Australia). Presentation title: *Clinical and Commercial Considerations for Delivery of RNAi Molecules*
2. **Prof Mark Kendall**, Vaxxas Pty Ltd and University of Queensland (Australia). Presentation title: *Taking the leap: from an idea in an academic lab towards a commercial product*
3. **Dr Sridhar Iyengar**, AgaMatrix (USA). Presentation title: *Kitchen Counter to the Genius Bar*
4. **Dr Paul Kelly**, OneVentures Pty Ltd (Australia). Presentation title: *So you think your innovation can change the world. How do you get investors to back you and get the best out of your investors?*
5. **Dr Greg Roger**, Cryptych Pty Ltd (Australia). Presentation title: *Achieving Success with your Innovation*

1. **Broader benefit to the Australian nanotechnology community**

There is a global unmet need to cure and prevent diseases for which we currently lack efficient treatments and which cause suffering and a shortened life expectancy. The ageing population, the high expectations for improved life quality and the changing lifestyle also call for improved, more efficient and affordable healthcare.

NanoMedicine, the application of nanotechnology in health care, offers numerous promising possibilities to significantly improve medical diagnosis and therapy, ultimately leading to higher standards of living. Furthermore, nanomedicine is an important strategic issue for sustainable competitiveness in Australia. The global competition in the field is very strong and the strategic importance of nanomedicine is being increasingly recognised by industry and government around the world.

Australia is facing strategic challenges in the field of health due to issues such as an ageing population, negative environmental effects on personal health and a demand for improved personal healthcare

Healthcare expenditures presently account for 10% of gross domestic product (GDP) in industrialised countries and are expected to grow at an average of 6% pa in the future. Nanomedicine offers numerous promising possibilities to significantly improve medical diagnosis and therapy and the field thus has a large potential for developing public welfare and economic growth. There is a large industrial enthusiasm for nanomedicine, with the US National Science Foundation has estimated that by 2015 half of the world's pharmaceutical industry products will be made with nanotechnology, and that the contribution of products incorporating nanotechnology to the global economy will be around \$1 trillion.

So to the question, has nanomedicine impacted human health? The answer is yes. High profile groups like the UK based Macmillan Cancer Support reported "a dramatic increase in the median cancer survival times over the past 40 years. Coupling nanotechnology drug delivery (NDD) methods with improvements in diagnostic, we can expect that much more progress will be made in the next 10 years than in the previous 40."

2. **Size of Event - anticipated number of attendees ; anticipated number of international attendees**

The conference attracted some 220 attendees representing 22 countries. The five plenary speakers were joined by a further 46 invited. The conference also saw 53 oral presentations and over 43 posters.

3. **Quality of plenary speakers**

Five plenary speakers led the program these being:


- **Professor Mark E Davis:** California Institute of Technology (USA)
- **Professor Shana Kelley:** University of Toronto (Canada)
- **Professor Jason S Lewis:** Memorial Sloan-Kettering Cancer Center (USA).
- **Professor Tanya Monro:** The University of Adelaide (Australia)
- **Professor Andrew Whittaker:** Australian Institute for Bioengineering and Nanotechnology, The University of Queensland (Australia)

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○ **Branding of ANN during the conference**

- ***Logo and acknowledgement on overhead slides before/after session***
- ***Verbal acknowledgement of ANN as a sponsor***

- **Acknowledgement during opening and closing ceremonies**
 - At the conference opening, officiated by ACNs Prof Justin Gooding, the following was stated while ANNs logo was on screen “to the Australian Nanotechnology Network we thank them for their assistance in providing support to Early Career Researchers”.
 - At the Closing address, Professor Maria Kavallaris (ACN) acknowledged all sponsors including ANN.
- **ANNs logo and 100 word description in Conference program**
 - The following words, contact details and logo appeared in the conference program

 <p>Australian Nanotechnology Network</p> <p>Australian Nanotechnology Network www.ausnano.net</p> <p>Ms Liz Micallef Network Manager</p> <p>Phone: (02) 6125 5952 ann@ausnano.net</p>	<p>The Australian Nanotechnology Network (ANN - Formerly ARCNN)'s mission to enhance Australia's Research in Nanotechnology and related areas, by effectively promoting and drawing together collaborations in this field.</p> <p>The Nanotechnology field is one of the fastest growing areas of research and technology. ANN is dedicated to enhancing Australia's research outcomes in this important field by promoting effective collaborations, exposing researchers to alternative and complementary approaches from other fields, encouraging forums for postgraduate students and early career researchers, increasing nanotechnology infrastructure, enhancing awareness of existing infrastructure, and promoting international links. ANN will achieve these goals through its dedication to bringing together all the various groups working in the field of Nanotechnology and related areas within Australia.</p>
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- **Acknowledgement with the ANN logo and preferred ANN URL link on Event website**
 - ANNs logo with connection to webpage can be viewed at http://www.oznanomed.org/index.php?option=com_content&view=article&id=52&Itemid=58
- **Acknowledgement with ANN logo in marketing activities (national and international) in the lead up to and during the conference**
- **Acknowledgement with ANN logo on any sponsor slides displayed over the duration**
 - All sponsors logo was included on a “sponsors power point” slide that was on a continuous loop before and after all sessions.

Yours sincerely,

Prof Maria Kavallaris
Conference Co- Chairs – International NanoMedicine Conference
Co-Director – Australian Centre for NanoMedicine

Prof Justin Gooding

NanoBio Australia 2014 held on the 6-10 July 2014 at the University of Queensland



AIBN Australian Institute for Bioengineering and Nanotechnology

To the ANN committee

Re: Funding of ECRs at the **NanoBio Conference, Brisbane, QLD July 2014.**

The ECR committee of the BioNano conference 2014 was successful in attaining a grant of \$5000 from the Australian Nanotechnology Network (ANN) towards the 5th International NanoBio Conference & 3rd International Conference on BioNano Innovation (ICBNI), held in Brisbane, from July 6-10, 2014.

This conference hosted six outstanding international plenary speakers including Dr Leroy Hood (Institute for Systems Biology), Professor Thomas Healy AO (The University of Melbourne), Professor Pamela Silver (Harvard University), Professor Molly Stevens (Imperial College, London), Professor Virgil Percec (University of Pennsylvania), as well as Dr Steve Turner (founder and CSO of Pacific Biosciences). These were followed by over 80 national and international invited presenters.

In brief:

- 171 Abstract submissions
- 43 total ECR speakers:
 - 10 international speakers from 7 countries (Belgium, NZ, Japan, China, UK, USA, Switzerland)
 - 33 National speakers 15 of them AIBN local speakers
- 128 posters including 16 international posters

The NanoBio 2014 conference featured a special dedicated symposium for ECRs on Thursday 7 July to encourage the next generation of scientists in the Nanotechnology and Bioengineering field. Overall, 171 abstracts were submitted, of which 43 impressive ECR's were selected for oral presentations. These included 10 international speakers from 7 countries (Belgium, NZ, Japan, China, UK, USA, Switzerland); 28 Australian speakers and 15 local speakers.

As voted by the judges, the most impressive talk of the day was by Mr Nathan Boase (The University of Queensland). Nathan presented his work on the development of hyperbranched polymers for applications in nanomedicine from the Whittaker group at AIBN. Nathan won the best oral presentation prize.

Runner-up for the ECR Oral Presentations was Dr Darren Korbie (University of Queensland). Darren presented his work on quality assessment of benchtop sequencing as a tool for rapid molecular profiling of breast cancer patients.

Separately, the NanoBio 2014 poster session took place throughout the conference with 128 posters submitted from around the world. The winning poster presentation was awarded to Ms Yuling Wang (The University of Queensland) who presented her research into biomarkers that can be used for the rapid diagnosis and treatment of diseases induced by pathogens. The runner-

up poster presentation was awarded to Mr Young-Seon Ko from the Korean Institute of Science and Technology. Young-Seon presented his work on the large-scale synthesis of silver nanoparticle-decorated silica hybrids as antibacterial agents on air filtration.

Through the funding provided by the ANN, the ECR committee of the NanoBio conference was able to provide support the following ECRs. Overall, funding was provided to assist 9 outstanding young researchers from 8 research institutes towards travel-associated costs and accommodation enabling them to present their research.

Title	Name		Affiliation	Presentation title
Dr	Yan	Jiao	University of Adelaide	Towards the Design of Metal-free Electrocatalyst for Clean Energy Conversion: DFT Studies
Dr	Peter	Roth	University of New South Wales	Well-defined Stimulus-responsive (Co)Polymers though Postpolymerization Modification: Novel Hydrophobically Modified Zwitterionic Copolymers
Dr	Sharath	Sriram	Royal Melbourne Institute of Technology	Functional oxide and nanomaterials for electronics and sensing
Dr	Xuan Thi	Le	Murdoch University	Anodic aluminium oxide membranes and composites in tissue engineering applications
Dr	Nick	Reynolds	CSIRO	ILQINS Hexapeptide, Identified in Lysozyme Left-Handed Helical Ribbons and Nanotubes, Forms Right-Handed Helical Ribbons and Crystals
Ms	Martina	Abrigo	Swinburne University of Technology	Development of Nanofibrous Meshes as Smart Dressings for the Healing of Chronic Wounds
Dr	Roey	Elnathan	University of South Australia	Engineering silicon nanowire arrays for delivering biomolecular cargos to mammalian cells
Ms	Karan	Gulati	University of Adelaide	In-bone therapeutic implants”: concept, fabrication and drug release
Mr	Dominic	Ho	University of Western Australia	Nanoparticle Arrays via Capillary Force Lithography as Potential Biochip Platforms

The ECR symposia as part of the NanoBio 2014 conference was organised by the ECR committee consisting of AIBN’s Simon Corrie (Chair), Alexandra Depelsenaire (Co-Chair), Paul Luckman, Axayacatl Gonzalez Garcia, Timothy McCubbin, Michael Crichton, Paolo Falcaro (CSIRO) and Ruth Neale.



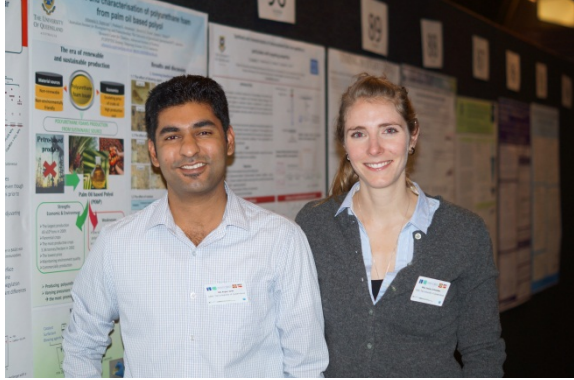
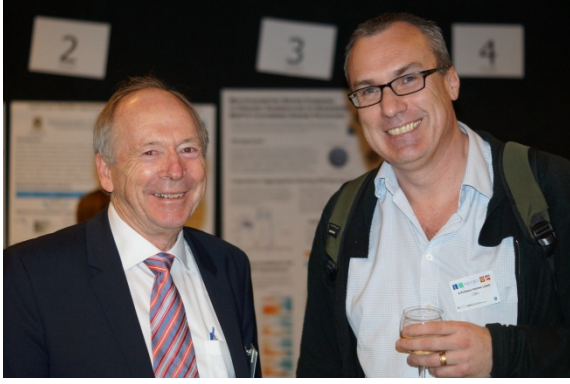
Figure 4: The main Auditorium at the NanoBio 2014 ECR symposia.



Figure 5 The ANN bursary awardees receiving their certificates.



Figure 6: Some of the NanoBio ECR-Conference committee.



**Molecular Modelling 2014: From Biomolecules to Materials held at the
Lamington National Park, Gold Coast on the 31st July to 2 August 2014
Email sent to Debra Bernhard on 28/1/2015**

Report on MM2014 : From Biomolecules to Materials

MM2014: From Biomolecules to Materials

The Association of Molecular Modellers of Australasia (AMMA) conference "Molecular Modelling 2014: From biomolecules to materials" (MM2014) was held from 30th July – 2nd August 2014 in the Gold Coast hinterland of South-East Queensland, Australia, in Lamington National Park, at the O'Reilly's Rainforest Retreat. Preceding the main conference was a student and early-career researcher forum, which was sponsored by University of Queensland's AIBN Centre for Theoretical and Computational Molecular Science (CTMCS). The conference was chaired by Prof Alan Mark and Prof Debra Bernhardt, and the forum by Dr David Poger and Dr Evelyne Deplazes

The Australian Nanotechnology Network funded travel bursaries for twelve students/early career researchers:

Reza Bakhtiari (PhD student, University of Western Australia), Lukas Wirz (PhD student, Massey University), Marta Enciso (ECR, La Trobe University), Yanan Lv (PhD student, Deakin University), Nastaran Meftahi (PhD student, La Trobe University), Majid Mortazavi (PhD student, Monash University), Alireza Nematollahi (PhD student, University of Sydney), Charlotte Petersen (PhD student, Australian National University), Christopher Pracey (PhD student, University of New South Wales), Nevena Todorova (ECR, RMIT University), Henry Wittler (PhD student, La Trobe University), Yuefeng Yin (PhD student, Monash University).

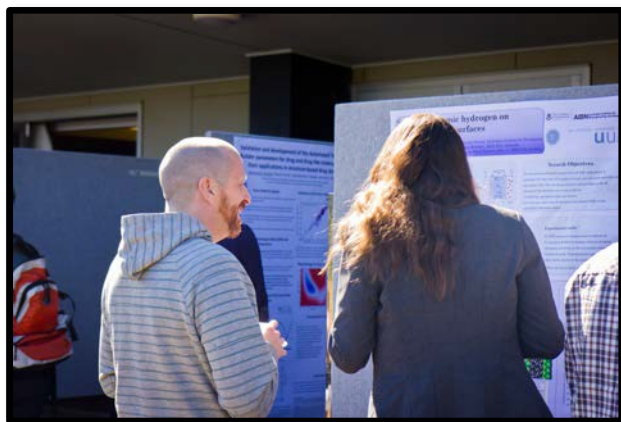
The one-day student and early-career researcher forum commenced on the afternoon of the 30th July and involved 50 participants. Plenary talks were given by Prof Wilfred van Gunsteren (ETH, Zürich) and Prof Billy Todd (Swinburne University, Melbourne), with thirteen selected talks presented by students and early career researchers. In addition, two students spoke at the main conference and the students also presented posters at the main conference. Oral prizes were awarded to students Amanda Buyan (University of Oxford, UK) and Lachlan Casey (University of Queensland) and poster prizes to Lang Liu (University of Queensland) and Nandhitha Subramanian (University of Queensland).

The two-day main conference commenced on the afternoon of the 31st July and attracted 112 participants including 45 students. There were 18 international delegates.

The plenary speakers were Prof Denis Evans (ANU, Canberra), Barbara Kirchner (Universität Bonn, Germany), Prof Wilfred van Gunsteren (ETH, Zürich) and Prof Billy Todd (Swinburne University, Melbourne). In addition 4 keynote, 8 invited and 17 selected talks were given under the themes of "Nanoscale Materials", "Membranes", "Nonequilibrium systems and Transport", "Biomolecules", "Materials", "Coarse-Grained Simulations" and "*Ab initio* Calculations".

The Association of Molecular Modellers of Australasia Medal Lecture "The Future of Quantum Chemistry" was presented to Prof Peter Gill (ANU, Canberra.) during the conference.

Photos taken during the conference



3rd Biennial Conference of the Combined Australian Materials Societies - CAMS 2014 held at the University of Sydney on the 26-28 November 2014

CAMS 2014 – Report to ANN

Conference activity purpose

The Combined Australian Materials Societies Conference, CAMS2014 is a forum for experts to discuss new scientific and technological developments in the exciting fields of ceramics and materials.

Including world-renowned invited speakers, an intensive scientific program featuring five concurrent streams, and exciting social events – this is the premium event on the Australian materials calendar. CAMS2014 featured an innovative program that reflects the multi-disciplinary nature of materials science and engineering. CAMS2014 was targeted at engineers and scientists from all walks of life. Special focus was been directed towards younger professionals and students.

Participant numbers

306 delegates attended the conference

Outcomes

The conference was well attended, was completed on budget, and was widely heralded to be a success. Many of the presenters were early career researchers and students.

Details of expenditure

ANN funding was used to provide bursaries to students and ECRs attending the meeting

Flexible and Stretchable Electronics, Sensors, and Photonics with High Temperature Oxides	Madhu	Bhaskaran	Photonics, Sensors & Optoelectronics
Effects of ion irradiation and temperature on the microstructural evolution of a Ni-Mo-Cr-Fe alloy	Massey	de los Reyes	Materials for Extreme Environments
The effects of graphene/graphene oxide dopants on the critical current density of MgB ₂ superconductors	Kaludewa	De Silva	Nanostructured & Nanoscale Materials
Conductive hydrogels for soft, deformable electrodes	Rylie	Green	Biomaterials
Surface characterisation of particles by in-situ electrokinetic analysis	Dorian	Hanaor	Advances in Materials Characterisation
Melt compounding for elastomer/graphene composites	Sherif	Araby	Microstructure & Properties of Composites
Applications of Photochromic Sub-Stoichiometric Tungsten Oxides	Aaron	Colusso	Materials for Energy Generation, Conversion & Storage

The role of solutes when
processing Al-Sc alloys by severe
plastic deformation

Katja

Eder

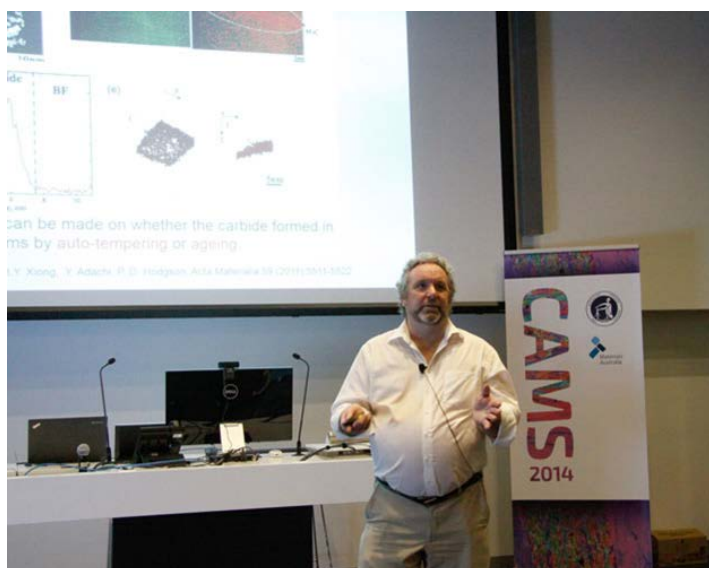
Nanostructured & Nanoscale
Materials

Formation of nanoporous platinum
sponges by de-alloying AlxPt

Supitcha

Supansomboon

Porous Materials



Conference on Optoelectronic and Microelectronic Materials and Devices (COMMAD2014) held at the University of Western Australia on the 14-17 December 2014

COMMAD 2014: 14-17 December, 2014

(Conference on Optoelectronic and Microelectronic Materials and Devices)

The COMMAD 2014 Conference was held at The University of Western Australia in Perth, from 14-17 December, 2014. The conference brought together world leaders and Australian ECR's and Postgraduate research students working in the area of optoelectronic and microelectronic materials and devices to discuss current and future research and industrial developments in these areas.

The Conference started on Sunday, 14 December, 2014, with an ANFF one day Short Course on the '*Introduction to nano-fabrication technologies*', and was attended by 55 delegates.

The workshop aimed to assist post-graduate, post-doctoral and early career researchers understand the basic principles of fabrication of semiconductor, optic and photonics devices, and the range of facilities and expertise they have at their disposal through the Australian National Fabrication Facility (ANFF). The workshop concluded with a tour of the ANFF-WA laboratories at UWA.

The Conference was officially opened on Monday, 15 December, 2014, by Professor Peter Klinken, the new Chief Scientist of Western Australia.

There were 109 conference participants comprising both Australian and international participants. This was a truly international conference, and countries represented in the delegation included: Canada, China, Croatia, France, Germany, India, Japan, New Zealand, Poland, and USA.

One of the core objectives of the conference was to highlight the work of outstanding young Australian researchers who are making significant contributions in the areas of microelectronics, optoelectronics and micro-electro-mechanical systems (MEMS). These young researchers were financially supported by the ANN to make poster and oral presentations at the conference.

The prize of \$200 for the best Student Poster presentation was awarded to Mr Armandas Balčytis, Postgraduate student Swinburne University of Technology, and the prize of \$200 each for the best Oral presentations was awarded to Dr Monishka Narayan, ECR at Charles Darwin University, and Mr Damon Carrad, Postgraduate student at University of New South Wales.

The sponsorship provided by the Australian Nanotechnology Network was used to support 20 Interstate Postgraduate students and ECR registrations from ANU, UNSW, Charles Darwin University, U Melbourne, U Queensland and Swinbourne University .

List of sponsored attendees.

Mr	Shuai	Li	The Australian National University
Mr	Sanjoy	Nandi	The Australian National University
Mr	Parvathala Reddy	Narangari	The Australian National University
Mr	Yesaya	Wenas	The Australian National University
Mr	Damon	Carrad	University of New South Wales
Mr.	Jian	Chen	University Of New South Wales
Mr	Jan Goeran	Gluschke	University Of New South Wales
Miss	Karina	Hudson	University Of New South Wales
Mr	Ruoyu	Li	University Of New South Wales, School Of Physics
Mr	Cai Johnny	Tang	University Of New South Wales, School Of Physics
Dr	Monishka	Narayan	Charles Darwin University
Mr	Gary	Agnew	The University of Queensland
Mr	Alireza	Mowla	The University of Queensland
Mr	Zhi	Zhang	The University of Queensland
Miss	Yichao	Zou	The University of Queensland
Mr	Armandas	Balcytis	Swinburne University Of Technology
Mr	Morteza	Aramesh	University of Melbourne
Mr	Herianto	Lim	University of Melbourne
Mr	Evgeniy	Panchenko	University of Melbourne
Mr	Michael	Stuiber	University of Melbourne

WEBSITE

**NANOTECHNOLOGY FACILITIES
AND CAPABILITIES REGISTER**

NEWSLETTER

MEMBERSHIP

PLANNED 2015 ACTIVITIES

WEBSITE

<http://www.ausnano.net>

The ANN Website is a very popular website and as at the end of 2014 it received more than 7,600,000 hits to the site, and it is believed that a significant amount of these are from Australia, and there is also interest from a number of other countries.

Website contains among other things:

- the lists of members and Research Groups affiliated with the network,
- online applications for members
- Online applications for grants
- Nanotechnology Facilities and Capabilities Register
- Reports from Young Nano Ambassadors
- Employment Opportunities
- Links to other websites and events

The website is continually being maintained and updated and there are links to various sites including various surveys, other networks and related activities.

NANOTECHNOLOGY FACILITIES AND CAPABILITIES REGISTER

The Nanotechnology Facilities and Capabilities Register was established at the end of 2006 and the list of registered facilities and their capabilities can be accessed on the following page <http://www.ausnano.net/index.php?page=facilities>

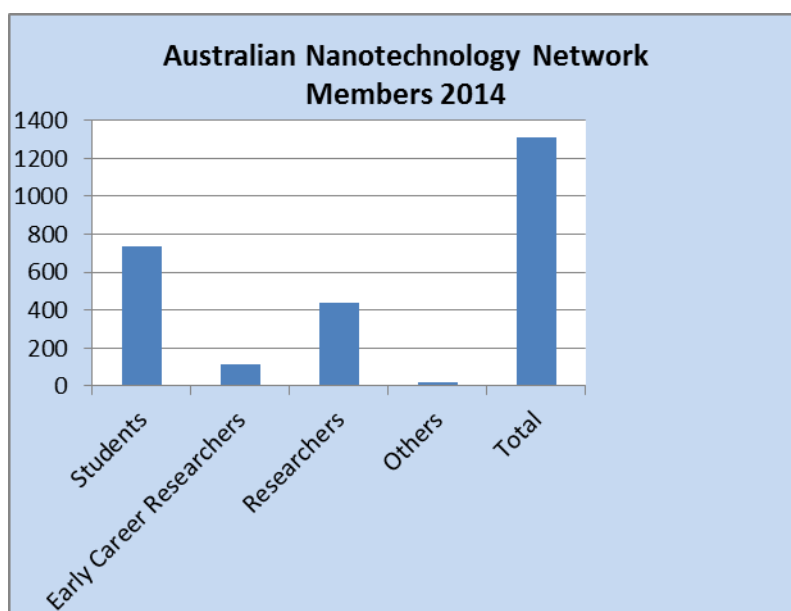
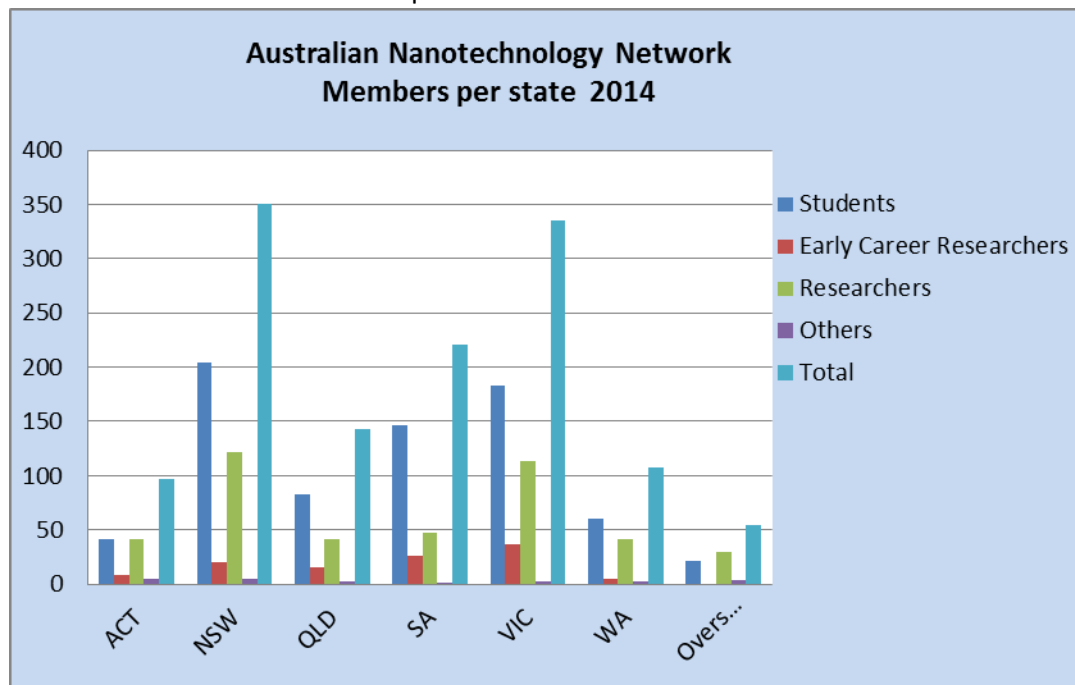
Members and visitors to the site are able to access specific nanotechnology facilities and expertise that is available across Australia.

NEWSLETTER

A newsletter which is sent to all members is another means of communication that ANN uses as an information management tool. The newsletter is sent out every six months and details information and events held in the field on Nanotechnology in Australia. Newsflashes are released in between newsletters to make members aware of events with a short deadline.

MEMBERSHIP

The ANN membership consists of established researchers, Early Career Researchers, PhD students whose research field is in the area of Nanotechnology. It also consists of members from Government departments and business.



State	Students	Early Career Researchers	Researchers	Others	Total
ACT	41	9	42	5	97
NSW	204	20	122	5	351
QLD	83	15	42	3	143
SA	147	26	47	1	221
VIC	183	37	113	2	335
WA	60	5	41	2	108
Overseas	21		30	4	55
TOTAL	739	112	437	22	1310

PLANNED 2015 ACTIVITIES

The Australian Nanotechnology Network (ANN) plans to continue funding Workshops, Conferences, Forums, encouraging and supporting participants in getting together and networking for the growth in the research of Nanotechnology in Australia.

The ANN will be holding a **Nanotechnology Entrepreneurship Workshop for Early Career Researchers on the 10-11th June 2015 at Griffith University, Gold Coast Campus.**

There will be a continuation of the successful Overseas Travel Fellowships, Short and Long Term visits and Young Nanoscience Ambassador Awards.

To encourage collaborations among its members the Following Events are planned to be sponsored:

- **7th Biennial Australian Colloid and Interface Symposium (ACIS2015)**
01/02/2015 - 05/02/2015 - Hotel Grand Chancellor, Hobart
- **6th International Nanomedicine Conference** - *06/07/2015 - 08/07/2015 - Coogee, Sydney*
- **35th Polymer Australasian Symposium** *12/07/2015 - 15/07/2015 - QT Hotel, Gold Coast*
- **2nd Asia Oceania Conference on Neutron Scattering**, *19/07/2015 - 23/07/2015 - Novotel Manly Pacific, Sydney*
- **9th International Mesosstructured Materials Symposium (IMMS-9)** - *17/08/2015 - 20/08/2015 - Brisbane Convention and Exhibition Centre*
- **Conference on Laser Ablations COLA 2015** - *31/08/2015 - 04/09/2015 - Pullman International, Cairns, Queensland*
- **NanoS-E3 2015** - **International School and Workshop on Nanotechnology**
27/09/2015 - 02/10/2015 - Peppers Salt Resort, NSW
- **Recent Progress in Graphene and Two-dimentional Materials Research(RPGR2015)**
25/10/2015 - 29/10/2015 - Lorne, Victoria

The management committee has also been involved in preparing for the **International Conference on Nanoscience and Nanotechnology (ICONN2016)** which will be held at the National Convention Centre in Canberra on the 7-11th February 2016.

ICONN 2016

7-11 Feb 2016

National Convention Centre, Canberra

The 2016 International Conference On Nanoscience and Nanotechnology (ICONN 2016) aims to bring together Australian and International communities working in the field of nanoscale science and technology to discuss new and exciting advances in the field. ICONN will cover nanostructure growth, synthesis, fabrication, characterization, device design, theory, modeling, testing, applications, commercialisation, and health and safety aspects of nanotechnology.

The conference will feature plenary talks followed by technical symposia (parallel sessions) consisting of invited talks, oral and poster presentations on the following topics: Nanomaterials, Nanobiotechnology, Nanoelectronics, Nanophotonics, Computational Nanotechnology, Nanocharacterisation, Nanotechnology for Energy and Environment & Commercialisation, Safety and Societal Issues of Nanotechnology.

Plenary Speakers

Nobel Laureate W. E. (William Esco) Moerner, Stanford University
Professor Ortwin Hess, Imperial College London
Professor Stephen Quake, Stanford University
Professor Albert Polman, FOM Institute AMOLF, Amsterdam
Professor Paul S Weiss, University of California Los Angeles
Professor John A Rogers, University of Illinois at Urbana Champaign
Professor Joseph Wang, University California San Diego
Dr. Heike Riel, IBM Research Zurich

- Call for Abstracts Open: 31st July 2015
- Submission of Abstract Deadline: 20th September 2015
- Notification to Authors: 31st October 2015
- Early-bird registration deadline: 15th December 2015

Conference Co-Chairs:
Professor Chennupati Jagadish &
Professor Hoe Tan



www.ausnano.net/iconn2016

