Australian Nanotechnology Network

# ANNUAL REPORT

2016

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# Mission Statement and Objectives

## MISSION STATEMENT

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

Network was created in 2004 by four seed funding groups 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, CSIRO, 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

# MISSION STATEMENT AND OBJECTIVES

## 2016 IN REVIEW

The work in 2016 was focused on enhancing the funding of programs and events related to Nanotechnology around the country.

Held the International Conference on Nanoscience and Nanotechnology

5 Young Nano Ambassador Awards

1 Short Term Visits

2 Long Term Visit

10 Overseas Travel Fellowships

7 Events sponsored by ANN

1 Distinguished Lecturer tour

## STRUCTURE AND MANAGEMENT

The Australian Nanotechnology Network 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 Distinguished Professor Chennupati Jagadish.

# MISSION STATEMENT AND OBJECTIVES

### *Management Committee Members*

The management committee members participate in committee meetings. They serve on the Working Group sub committees, represent the Network and publicize 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.

**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 - (till March 2016) |
| Prof. Peter Majewski | University of South Australia |
| Prof Michael James | Synchrotron Light Source Australia |
| Prof Ian Gentle | University of Queensland |

# MISSION STATEMENT AND OBJECTIVES

***Visits Working Group***

| | |
|---|---|
| A/Prof Adam Micolich | University of New South Wales - (till March 2016) |
| Dr Dane McCamey | University of New South Wales |
| Prof. Deb Kane | Macquarie University |
| Prof Gordon Wallace | University of Wollongong - (till March 2016) |
| Dr Michael Higgins | University of Wollongong - (from March 2016) |
| Ms Siobhan Bradley | University of South Australia- (till February 2016) |
| Ms Gayathri Rajeev | University of South Australia- (from February 2016) |

***Education Working Group***

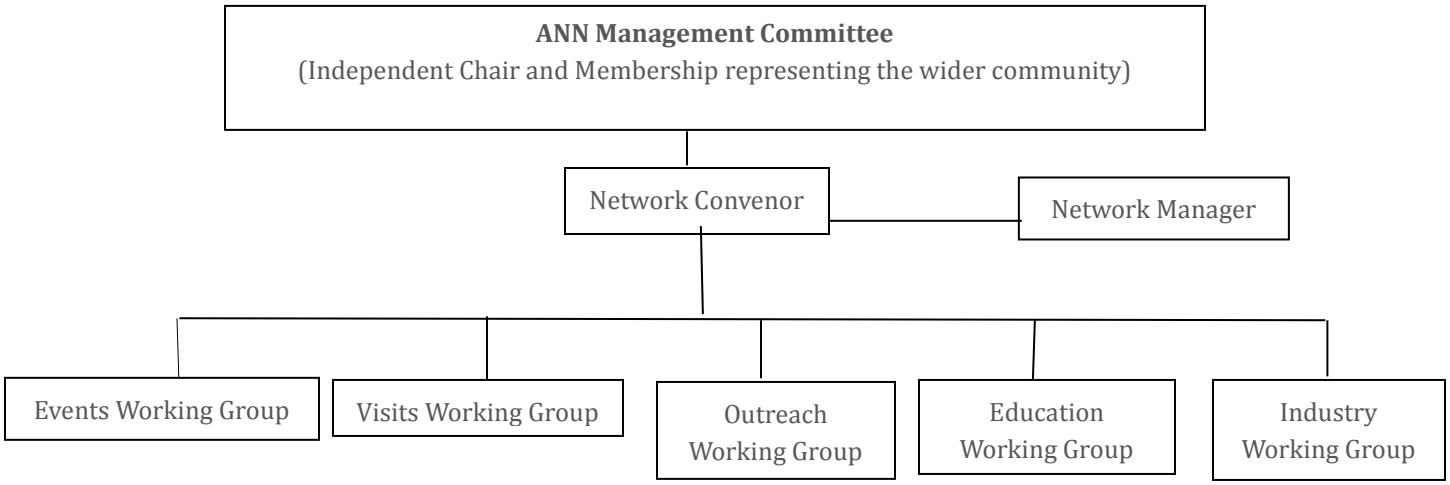
| | |
|---|---|
| Prof. Max Lu | University of Queensland - (till February 2016) |
| Prof Terry Turney | Micronisers Pty Ltd and Monash University |

*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 Herrar | 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 2016**

## Young Nanotechnology Ambassadors program

- Australian Capital Territory - Ankita Gagrani from the Australian National University
- Western Australia - Ms Jessica Kretzmann – The University of Western Australia
- South Australia – Ms Rajni Garg – University of South Australia
- New South Wales - Ms Katherine Mc Donnell –University of Sydney
- South Australia – Mostafa Rahimi Azghadi – The University of Adelaide

## Short Term Visits

- Ms Margaryta Sheliakina from the University of Queensland to visit the University of New South Wales

## Long Term Visits

- Mr Chengjun Zou from the University of Adelaide visit to the Functional Materials and Microsystems Research Group AT RMIT University
- Mr Edward Jiang from the University of Queensland visit to Deakin University

## Overseas Travel Fellowships

- Mr Mitchell Nothling from the University of Melbourne visit to the University of California, Santa Barbara for a period of six months
- Mr David Waddington from the University of Sydney visit to the Martinos Centre at Massachusetts General Hospital for a period of six weeks
- Mr Hamish Brown from the University of Melbourne visit to the University of Tokyo for a period of three months
- Dr Daniel Sando from the University of New South Wales visit to the Institute of Physics at the Taiwanese National Laboratory for a period of one month.
- Mr Jason Brenker from Monash University visit to the Paul Scherrer Institute (PSI) in Villigen Switzerland for a period of four months
- Mr Xiaorui Zheng from Swinburne University visit to the University of California (San Diego) for a period of three months.

# ACTIVITIES UNDERTAKEN BY ANN

- Ms Weijie Li from the University of Wollongong visit to Dongguk University in Seoul, Korea for a period of six months
- Mr Fran Kurnia from the University of New South Wales visit to the Centre for Nanophase Materials Sciences at Oak Ridge National Laboratory, USA for a period of three weeks
- Miss Yanyan Jiang from the University of New South Wales visit to the University of Colorado, Boulder, USA for a period of nine weeks
- Mr. MD Sharafat Hossain from the University of Melbourne visit to the University of California, Berkeley, USA for a period of three months
- Ms Mun Teng Soo from the University of Queensland visit to the Institute Microstructure and Properties of Advanced Materials, Beijing University of Technology (BJUT), China, for a period of nine weeks.
- Dr. Markus Muellner, School of Chemistry, University of Sydney visit to Aalto University, Finland for a period of eight weeks.
- Dr Tanveer Hussain from the University of Queensland visit to the University of Texas, USA for a period of twelve weeks.
- Ms Emma Brisson from the University of Melbourne visit to the University of Warwick for a period of three months.
- Dr Roey Elnathan from the University of South Australia visit to the Max Planck Institute for Medical Research, Stuttgart, Germany for a period of four weeks.
- Ms Larissa Huston from the Australian National University visit to the Oak Ridge National laboratories, Tennessee, USA for a period of twelve weeks.

## Workshops and Events Sponsored by ANN

- 7th International Nanomedicine Conference, 27/06/2016 - 29/06/2016 - Coogee Beach, Sydney
- 5th International Symposium on Graphene Devices (ISGD-5), *11/07/2016 - 14/07/2016* - Griffith University - Southbank
- 8th International Symposium on Nano and Supermolecular Chemistry, *13/07/2016 - 16/07/2016* – Brisbane
- 36th Australasian Polymer Symposium (36APS) *20/11/2016 - 23/11/2016* - Lorne, Victoria
- 9th International Membrane Science and Technology Conference (IMSTEC) *05/12/2016 - 08/12/2016* - Adelaide Convention Centre
- 13th International Conference on Optoelectronics and Microelectronics Materials and Devices- COMMAD 2016 *12/12/2016 - 14/12/2016* - Colombo House - University of New South Wales
- Western Australian Symposium of Nanobiotechnology, *20/12/2016 - 21/12//2016* - University of Western Australia

- **Distinguished Lecturer Tour**
- **Prof Fabio Beltram.**
  *29/01/2016 - 04/02/2016* - **Brisbane, Melbourne and Perth**

# ACTIVITIES UNDERTAKEN BY ANN

## International Conference on Nanoscience and Nanotechology 2016

Another successful International Conference on Nanoscience and Nanotechnology (ICONN 2016) hosted by the Australian Nanotechnology Network was held in Canberra in February 2016. ICONN2016 attracted six hundred delegates from nineteen countries and was chaired by Prof Chennupati Jagadish and Prof Hoe Tan from the Australian National University.

A short course on the Introduction to Nanofabrication Technologies was held on the first day, was organised by, and featured speakers from the Australian National Fabrication facility.

8 Plenary speakers including Nobel Laureate, Prof W E Moerner and thirty six invited speakers gave a remarkable synopsis of recent developments in the field. ICONN also attracted, 235 contributed talks and 279 poster presentations representing Europe, Asia Pacific, Eurasia and North America.

A Women in Nanotechnology Forum hosted by Prof Deb Kane was held on the 2nd day and a meeting with Nobel Laureates Prof William Moerner and Prof Brian Schmidt hosted by Prof Andrew Holmes (President, Australian Academy of Science) was held in the evening of the third day.

The social side of ICONN2016 commenced with the welcome reception in the exhibition area which comprised of 25 exhibition booths. This was a great networking opportunity for the students, scientists and stake holders from academia, government laboratories and industry. Further social opportunities were provided with two happy hours which were combined with the presentation of 279 posters. The Conference dinner, was a highlight with a number of awards presented to speakers, a delicious meal and entertainment to dance the night away.

# ACTIVITIES UNDERTAKEN BY ANN

Below is the list of Plenary and Invited speakers attending ICONN 2016

**Plenary Speakers**

**Nobel Laureate -Professor W E Moerner** *Department of Chemistry, Stanford University, California*
**Single-Molecule Nanoemitters, Blinking, and Photocontrol as Foundations for Super-Resolution Microscopy**

**Professor Ortwin Hess-** *Faculty of Natural Science, Imperial College, London*
**Plasmonic Stopped-Light Lasing: A Route to Cavity-Free Nanolasing**

**Professor Stephen Quake-** *Department of Bioengineering, Stanford University*
**Single Cell Genomics**

**Professor Albert Polman**
*FOM Institute AMOLF- Foundation for Fundamental Research on Matter, Amsterdam*
**Nanophotonics: controlling light at the nanoscale**
**Professor Paul S Weiss -** *University of California, Los Angeles*
**Cooperative Function in Atomically Precise Nanoscale Assemblies**

**Professor John A Rogers -** *University of Illinois at Urbana Champaign*
**Semiconductor Nanomaterials for Biodegradable Electronics**

**Professor Joseph Wang-** *Department of Nanoengineering, University California San Diego*
**Nanomachines: Designs and Applications**

**Dr Heike Riel -** *IBM Research Zurich*
**Semiconductor Nanowires for Nanoelectronics**

***Invited Speakers***

**Nanomaterials**

| | |
|---|---|
| Dr Matthew Hill | CSIRO, Clayton Vic |
| A/Prof Shannon Notley | Australian National University, Canberra |
| Professor Maria Forsyth | Deakin University, Vic |
| Professor Martina Stenzel | UNSW, NSW |
| A/Prof Alois Lugstein | Vienna University of Technology, Austria |
| Professor George Pharr | University of Tennessee, USA |
| Professor Jeff Snyder | Northwestern University, USA |
| Professor Pagona Papakonstantinou | ERI University of Ulster, Ireland |

**Nanobiotechnology**

| | |
|---|---|
| Prof Cameron Alexander | Nottingham University, UK |
| Professor Dayong Jin | Macquarie University, NSW |
| Professor Andy Sparkowitz | Stanford University, USA |
| Professor Andrew Whitaker | University of Queensland - Queensland |

| | |
|---|---|
| Professor Christy Landes | Rice University, USA |
| Professor Sarah Heilshorn | Stanford University, USA |

**Nanoelectronics**

| | |
|---|---|
| Prof. Jonathan Bird | SUNY Buffalo, U.S.A |
| Professor Saskia Fischer | HU Berlin, Germany |
| Dr Kirsten Moselund | IBM Zurich, Switzerland |
| Prof. Marco Rolandi | U. Washington, U.S.A |

**Nanophotonics**

| | |
|---|---|
| Professor Stephan Link | Rice University, USA |
| Dr Peter Banzer | Max Planck Institute, Germany |

**Computational Nanotechnology**

| | |
|---|---|
| Dr Stefano Corni | Centro S3 CNR Istituto di Nanoscienze, Modena,Italy |
| Professor Alexander Shluger | University College London |
| Professor Florent Calvo | Universite Joseph Fourier,Grenoble France |

**Nanocharacterisation**

| | |
|---|---|
| Professor Tomonobu Nakayama, PhD | University of Tsukuba |
| Professor Quentin Ramasse | Daresbury Lab,Warrington, UK |
| Professor Odile Stephan | Universite Paris Sud Orsay , France |
| Dr Jesse Clark | Stanford University, USA |

**Nanotechnology for Energy and Environment**

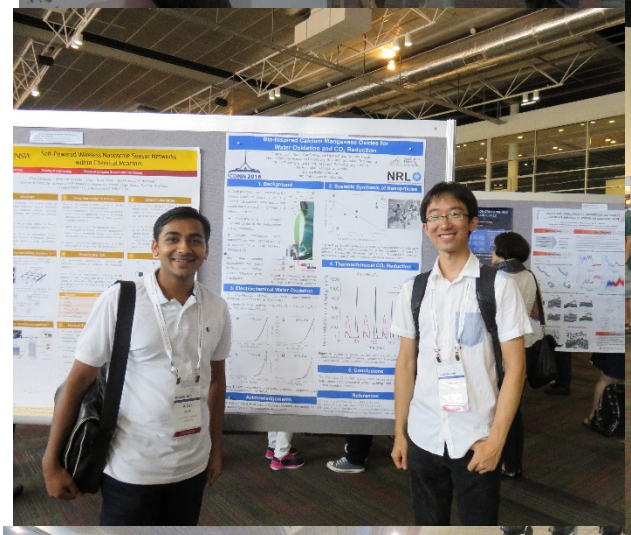
| | |
|---|---|
| Prof Wonyong CHOI | Pohang University of Science and Technology (POSTECH), Korea |
| A/Prof Thatt Yang, Timothy TAN | Nanyang Technological University, Singapore |
| Professor Lin Guo | Beihang University, China |
| Professor Shin-ichi Orimo | Tohoku University, Japan |
| A/Prof Dongling Jiang | National Institutes of Natural Sciences, Japan |

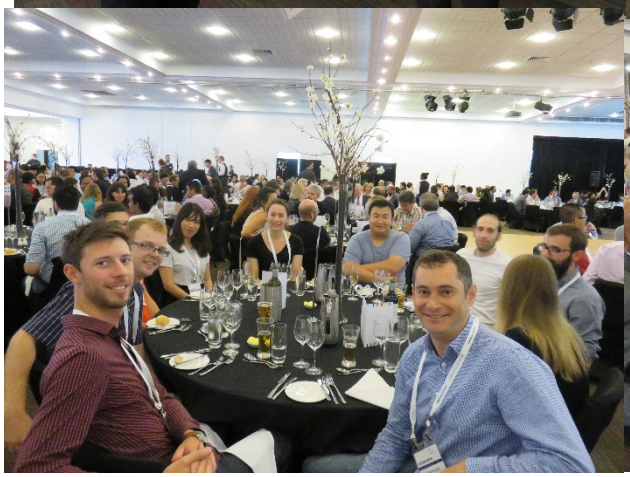
**Commercialisation, Safety & Societal Issues of Nanotechnology**

| | |
|---|---|
| Prof Darren Martin | University of Queensland |
| Dr Asa Jamting | National Measurements Institute, Sydney |
| Dr Stefan Harrer | IBM Australia |

More information on this year's program, conference themes, symposia chairs and co-chairs can be accessed on the following http://www.ausnano.net/iconn2016/

# ACTIVITIES UNDERTAKEN BY ANN



# ACTIVITIES UNDERTAKEN BY ANN


# Young Nano 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 2016

## AUSTRALIAN CAPITAL TERRITORY - ANKITA GAGRANI FROM THE AUSTRALIAN NATIONAL UNIVERSITY

### *Big opportunities in the science of small*

### Introduction of nanotechnology to high school students of ACT

As a student of material science, tailoring the essential structures of materials at the nanoscale for achieving specific properties has been of great interest to me. Unfortunately, secondary school and university students of Australia do not seem to have passion about science. Figures from Federal Education Department suggest that 20 years ago 94 per cent of year 11 and 12 students used to enrol in science subjects, but recently the figure has dropped to 51 per cent, resulting in declination of Australia's place in a global comparison of the scientific literacy of students. Also, a recent report, "The continuing decline of science and mathematics enrolments in Australian high schools" by John Kennedy, Terry Lyons and Frances Quinn demonstrated decreasing enrolment trends in STEM field. Main reasons were described as difficult nature of scientific subjects and unawareness of the exciting job opportunities in both research and industrial sector.

After analysing the present situation, I realised a strong need to re-energise science by sparking the excitement of nanotechnology among the students by demonstrating its practical potential and exciting opportunities available across the globe by describing my previous experiences.

I contacted science teachers of various high schools and proposed the idea of introducing a unique aspect of science to school students.-*NANOTECHNOLOGY*!!

My proposal was welcomed by them and I received an overwhelming response for organizing a nanotechnology seminar in their respective schools. After being selected as young nanotechnology ambassador, I arranged the required resources for the workshop and fixed the schedule with schools.

Visits to Schools

I realised it is very important to introduce aspects of nanoscience to year 9 and year 10 students to make their mind more clear about the field of study in future. After the workshop in each school, students were very excited and wondered to know about the fascinating world of nanotechnology. Almost all the students had no idea that manipulation of materials at atomic level can lead to the door of unlimited possibilities for sustainable development of the planet. Moreover experimental demonstrations convinced them with the unique world of nanoscience. Each school visit was approximately more than an hour.

I visited following schools in ACT state:

| | |
|---|---|
| **Monday 23th May 2016**<br>**Caroline Chisholm School (Senior Campus)** 108<br>Hambidge Cres, Chisholm ACT 2905<br>http://www.chisholm.act.edu.au/ | **Tuesday 24th May 2016**<br>**Melrose High School**<br>Marr Street, Pearce 2607<br>http://www.melrosehs.act.edu.au/ |
| **Wednesday 22nd June 2016**<br>**Alfred Deakin High School**<br>Denison St, Deakin ACT 2600<br>http://www.adhs.act.edu.au/ | **Thursday 23rd June 2016**<br>**Alfred Deakin High School**<br>Denison St, Deakin ACT 2600<br>http://www.adhs.act.edu.au/ |

Due to high number of students (approx. 250) in Alfred Deakin School, four sessions were conducted on two different days (two sessions per day).

**Nanoscience Workshop**

***a) Powerpoint and Animations:***

During each visit, students were introduced to nanotechnology through a powerpoint presentation. The presentation included the idea of nanotechnology, different examples to demonstrate the nanoscale, tools to characterise nanomaterials and potential benefits of nanotechnology in medical , environmental, energy applications. Further, use of nanotechnology in normal products like sunscreen, water purifiers, self-cleaning windows, water resistant paints etc. were appreciated very well by students. I realised the possible difficulty in visualising nanoscale by students, hence a couple of animations/videos about nano-materials and cancer treatment using nano technology were also included in the presentation. Videos proved to be the powerful tool during the session as visual effects created more interest among the students. After presentation, short discussion session with students was organised. It involved clarifying their queries about application of nanotechnology, uniqueness of nano world and career paths related to the field. Further, for undertaking nanotechnology research during higher studies, a brief description of the courses required at the university level was provided. Hardcopies describing summary of presentation and experimental activities were distributed to students for future reference.

### b) *Experimental Demonstrations:*

After the presentation, simple experiments of nano science were demonstrated to make the fundamentals more clear and leave a lasting impact on the mind of the students

- **Magic Sand Experiment :** It enabled the students to understand the characteristics of hydrophobic coating. Students were able to appreciate that changing nanoscale affects the macroscale behaviour of material. Further a discussion about "self-cleaning of lotus leaf" and water resistant materials through a provided them a deep understanding of implementation of nanotechnology in the real world.

- **Surface Area Experiment: Aim** of the experiment was to demonstrate that due to high surface area of nanoparticles, there are more atoms on the surface to react, leading to high reactivity of nanoparticles. For demonstration, two tablets of Aspro Clear (effervescent tablets) were taken. One was finely crushed using mortar and pestle. Both of them were simultaneously dropped into two identical beakers filled with water. Students could clearly observe the faster reaction in the beaker containing crushed tablet. The experiment was followed by a discussion on nano catalysts.

- **Nanopaper:** During the demonstration, sample of nanopapers were distributed among students and the technique to produce nanopapers along with their possible applications in transparent and flexible screens, thin film transistors, organic shopping bags (to replace plastic), resistive paper touch screens etc. were discussed. The samples of nanopapers enabled them to appreciate the difference between normal paper and nanopaper.Idea of creating paper based solar cell and batteries appeared fascinating to majority of students.

- **Ethics in Nanotechnology:** The workshop was successfully concluded by summarizing the learnings along with a brief discussion of ethical and environmental issues in nanotechnology research. Students gained insight about research regulation and various policies.

## Outcomes

Following are the key outcomes of school visits:

- High school students did not any clue about the science at nano scale. The workshop proved to be highly beneficial in sparking their interest in a wonderful aspect of science.
- The program was highly welcomed by the science coordinators in school. Most of them expressed the interest for hosting a nano-science session every year for coming batches in the school.
- The wonders of nanoscience were such exciting for some students that they expressed interest to work on small nanotechnology related projects. I was offered to volunteer as science mentor of a year 9 student. At present, in coordination with Melrose High School, we are exploring potentially suitable nanotechnology projects for students.

*MomentsWithFutureScientists*


Image 1: Discussing about nano paper and flexible electronics with students at Alfred Deakin High School (Day-1)

Image 2; After Workshop at Alfred Deakin High School (Day-2)

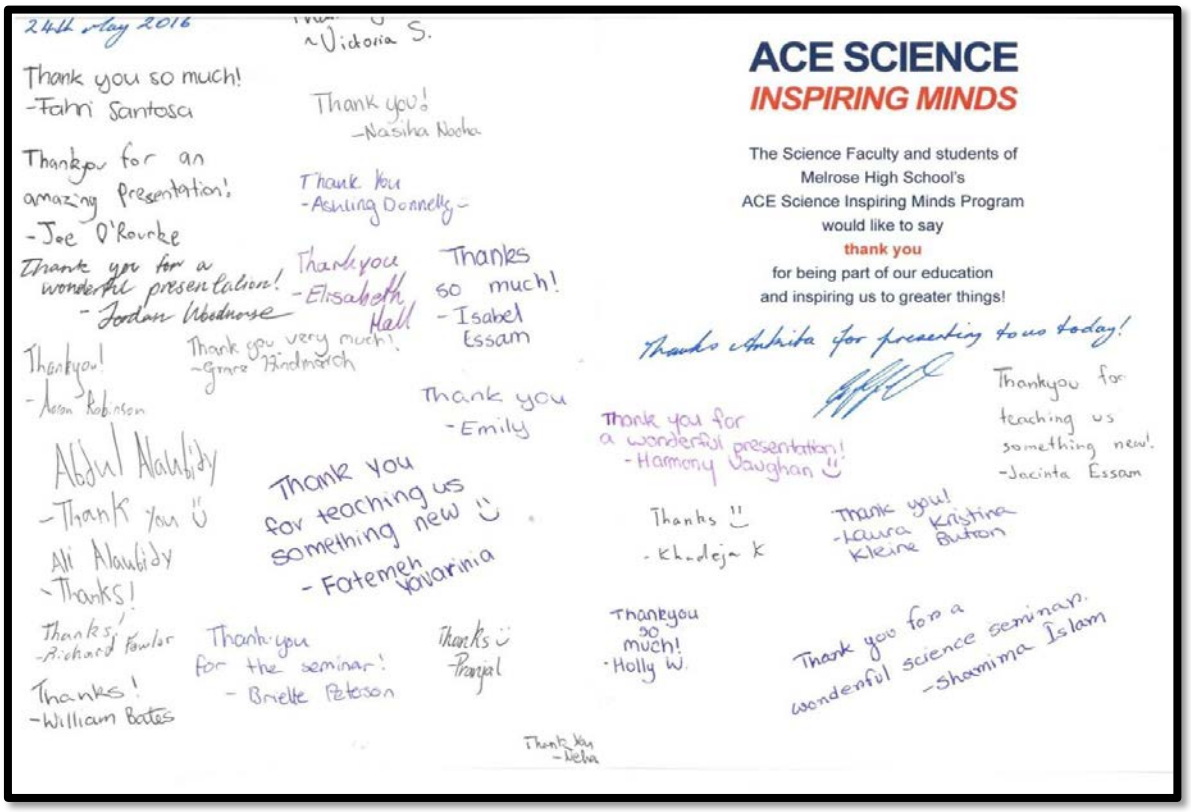



Image 3: Thanks note by students of Melrose High School

Image 4 : Demonstrating surface area effect at Caroline Chisholm School

## WESTERN AUSTRALIA - JESSICA KRETZMANN FROM THE UNIVERSITY OF WESTERN AUSTRALIA

Nanotechnology: getting to the bottom of things

ANN Ambassador School Visit Outcome

Jessica Kretzmann

**Introduction**

Science outreach programs are hugely beneficial to school students and teachers, because not only do they facilitate the introduction of new and exciting topics, but they also highlight science-related career possibilities that many students are unaware of. I believe outreach programs are particularly required in rural areas, where the students are, unfortunately, often at a disadvantage with fewer science related educational opportunities and resources, compared to students in metropolitan areas. Additionally, there is still a stigma among students associated with being openly passionate and excited about science. The combination of these factors means that students often go through science in school 'because they have to', without properly engaging in science. This is clear through my own schooling in both rural and metropolitan areas, and through my conversations with teachers and students during my last two years as ANN ambassador, where over the last two years I have visited eight schools (four in each of the South West and Wheatbelt regions of Western Australia), and Scitech's Innovation Festival and Science Café events.

Furthermore, nanotechnology has recently been introduced into the National Australian Curriculum in secondary schools. Through discussions with the staff at each of the schools, teachers are unanimously finding the requirement outline vague and difficult to teach, as nanotechnology is both a broad and a new learning area.

**Figure 1.** Year 10's from Cunderdin DHS after an eventful afternoon of demonstrations and many questions!

With support from ANN, my aim as the ANN Young Ambassador is to show students that anyone with a fundamental curiosity is already interested in science, and to show them some of the amazing opportunities a career in science can provide. I conveyed this message by drawing on my own experiences at school, and through my current situation as a PhD student at the University of Western Australia. In particular I talk to the students about some of the exciting opportunities I have had as a PhD student, such as the opportunity to travel around the world to attend conferences.

I firmly believe that outreach programs in schools are crucial to increase awareness of science-based careers, and enthusiasm for the subject. I'm particularly passionate about outreach activities to rural schools, and so visited schools throughout the Wheatbelt area of Western Australia.

**Schools Visited**

I visited four schools in the Wheatbelt area over the period of four days. Schools in the Wheatbelt region of Western Australia were chosen as I felt it was important to ensure regional students were given the opportunity to see these resources. As many schools in this region do not have the students or resources to hold upper school classes (years 11 – 12), presentations were given to lower school students (years 7 – 10). I felt this was an important target audience as many students are sent to boarding school early on if they find a passion that would require a university education. Additionally, for the students that continue schooling in the Wheatbelt area, subject selection occurs in year 10, with nanotechnology now in the school curriculum in year 11 chemistry.

With the support of the ANN through the nanotechnology student ambassador award I was able to develop and update the hands-on nanotechnology-related resources and demonstrations which the students were able to experience. Staff (including teachers, principals and lab technicians) also participated in the lessons and activities. The activities are all devised so as to be easily recreated and repeated by the teachers for later years. Therefore by engaging the teachers and having easily sourced materials for demonstrations, the ANN and DIISRTE funded project will have lasting effects for future students.

The activity stations were as follows:

1. Magnetics and Ferrofluids - students compared the interactions of large iron filings (in water) with a magnetic field, and the interactions of a ferrofluid (iron nanoparticles in water) in a magnetic field.

2. Hydrophobic surfaces - students looked at a variety of hydrophobic surface coatings (hydrophobic coatings on materials, and hydrophobic sand). Students learn that 'like dissolves like' in chemistry, but find it difficult to relate this knowledge to applications. The aim of this activity was to show that surfaces and materials can be modified to be either hydrophilic or hydrophobic, and to get students thinking about potential applications.

3. Nanoparticles for biological applications - the aims of this display was first to show how nanoparticles can be used to encapsulate drugs for better delivery, as well as to show how we can change the properties of nanoparticles in a controlled manner. Alginate with blue food dye and calcium chloride solutions were used to demonstrate how we can make polymer particles, and how we can encapsulate therapeutics. Additionally, students were shown gold nanoparticles at a range of different sizes, so the students saw how you can change the colour of gold with size.

4. Surface area to volume ratio, and smart metals - in this activity students compared heating a steel nail and steel wool, and they saw a difference in reactivity - steel wool burns due to the increased surface area to volume ratio. The students also had pieces of a smart metal alloy ('nitinol'). They were able to bend this metal out of its original shape, then watch it restore itself with gentle heating.


**Figure 2.** Year 10's from York DHS participating in "hands on" nanotechnology activities. **a**, surface area to volume ratio demonstration, **b**, Hydrophobic surface coatings, **c**, making polymer particles and looking at size effects of gold nanoparticles, **d**, ferrofluid.

Overall, I strongly believe that outreach programs are necessary to increase awareness of science-related career opportunities, especially in regional areas, and are welcomed by everyone involved, both teachers and students alike. With the support from the ANN I was able to visit four schools around the rural Wheatbelt area of Western Australia and engage with both students and teachers, giving them further insight into nanotechnology and careers in science. Using this approach, I believe the project will have lasting effects for future students.

Cunderdin DHS Monday 20/06/2016
Contact: Mathew Kennedy, mathew.kennedy@education.wa.edu.au
York DHS Tuesday 21/06/2016
Contact: Elizabeth Read, elizabeth.read@education.wa.edu.au
Quairading DHS Wednesday 22/06/2016
Contact: Chin Huan, chin.huan@education.wa.edu.au
Beverly DHS Thursday 23/06/2016
Contact: Sharyn Morrell, sharyn.morrell@education.wa.edu.au

## SOUTH AUSTRALIA – MS RAJNI GARG – UNIVERSITY OF SOUTH AUSTRALIA

### Nanotechnology- The Power of Small

The ANN young Nanotechnology ambassador award aims at creating awareness on Nanotechnology among high school students. I feel very fortunate and thankful to ANN for giving me an opportunity to visit the schools in South Australia and give an insight to the students on Nanoscience.

The four schools that I visited within South Australia were all regional school that include Naracoorte high school (9th August 2016), Keith Area School (10th August 2016), Bordertown high school (11th August 2016) and Kingston community school (12th August 2016). Each day was devoted to each school so that I could get to talk to most of the students. Thus I was able to conduct multiple sessions (one session/ hour) in each school. For an example: in Naracoorte, I ran 4 sessions that included Year 8, two sessions for Year 9 and fourth for Year 11.

My sessions included a presentation, some activities that were conducted in between the presentation to keep the interest of students in the topic followed by a short video. The presentation was made as simple as possible to make it easy for the students to understand the topic. Each topic of discussion was followed by an activity explaining the topic. They were discussed as follows:

1.) **Nanoscale:** In this part, I described how small a nanoscale using some examples. This was followed by an activity in which students/ volunteers were asked to calculate their height in nanometers. Students took a great interest in the activity and those with short height felt an immense pride in knowing that they are quite tall in terms of nanoscale.

2.) **Properties at Nanoscale:** This part of discussion included two main points and two activities mentioned as follows:

a). **Change in colour:** Students learnt that a material in bulk could have a different colour when it is reduced to nanoscale. They were given an example of cadmium selenide (CdS) quantum dots. To understand this point, volunteers conducted a very simple experiment that included the dilution of rose coloured vinegar in water. In each step of dilution, the color of vinegar disappeared but the smell persisted. This excited the interest of the students as they understood that how certain things that they can't even see with their naked eyes could still maintain its property.

b). **Change in properties:** Few examples were given in the discussion to clarify students that nanotechnology is not only about colour change but that it also has a potential to change the property of a material from bulk level. They were surprised to know that the commonly used Al (Al foils, tins) at nanoscale could combust in its contact with air. To explain this change in property, students were shown some graphite samples.

One that contained graphite powder, another with graphite powder mixed in a low boiling point solvent, and the last one was exfoliated graphite (graphene) dispersed in the same solvent. The students were so amazed to know that how just a change in the particle size of graphite changed it to a highly conductive material.

***Students looking at the Graphite, graphene samples (Naracoorte High school)***

3.) How small can we see? : In the discussion I explained the students that how small they could see with their own eyes and that to be able to see at nanoscale, scientists use some powerful microscopes. Volunteers ran a conductivity test using multimeter (purchased from Jaycar electronics) on ITO coated glass. Students were very surprised to see how an invisible coating can change the property of glass. This helped students to understand that at certain scale, it is almost impossible to see with your naked eyes.

4.) **Application:** I gave many examples to students where nanotechnology has been or will be used in next coming years. To keep an interest of the students, I planned to introduce a fun activity towards the end of my sessions where I asked the volunteers to play with kinetic sand that I purchased from Target and explained that why it felt so different than the normal sand.

***Students playing with Kinetic sand***

At last, we discussed the influence of nanotechnology on everyone's career in future. Also, I tried to encourage them totake an interest in the field by showing some of my recent conference visits to China and Brisbane. We talked about how I first got an interest in Nanotechnology and what made me pursue my PhD in Nanotechnology at University of South Australia. I ended up my presentation by showing them a video about nanoscale hydrophobic coatings which totally blowed their minds (https://www.youtube.com/watch?v=3ayRImPvcQU).

I feel very happy to be able to reach the students from regional schools as they get very less opportunities to get learn about new things happening around the world. In the end of the sessions, some of the students came up to me and thanked me for coming to their school and talking to them. This made my school visits totally worthwhile. Some students were also interested in some of my slides and video, so I emailed the science coordinators to forward it to students. I received lot of appreciation from the teachers. Some of the comments are mentioned below.

*"Hi Rajni, I have spoken to some students about your presentation and they were very interested in what you presented. I will pass your links on to staff and they will pass them onto any students who are interested. Thanks for coming, it was very interesting"*- Janine (Keith Area School)

*"Thanks Rajni - our staff really appreciated your time. I will pass it on. Cheers" John (Naracoorte High School)*

# YOUNG NANO AMBASSADOR AWARDS

## NEW SOUTH WALES - MS KATHERINE MC DONNELL –UNIVERSITY OF SYDNEY

Visits to Schools will take place in 2017

## SOUTH AUSTRALIA –MOSTAFA RAHIMI AZGHADI - UNIVERSITY OF ADELAIDE

Visits to Schools will take place in 2017

# 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.

## MS MARGARYTA SHELIAKINA FROM THE UNIVERSITY OF QUEENSLAND TO VISIT THE UNIVERSITY OF NEW SOUTH WALES

The ANN short travel visit funding was used to support a two week visit to the University of New South Wales to work with A/Prof. Adam Micolich on solid state organic electrochemical transistors based on the natural material melanin with a proton-transparent top gate contacts made of palladium hydride (PdHx).

Here at UQ we've been recently working on developing a new all-solid-state bioelectronic featuring the naturally occurring biopolymer melanin. Both traditional organic electrochemical transistors (OECT) and solid state devices use a PEDOT:PSS film as a transistor channel. The difference is that for solid state OECTs the ions that gate it come from a solid-state overlayer made of melanin rather than immersion in a liquid electrolyte. Upon application of a small positive gate voltage, the transistor turns "off" as protons generated in the melanin film are driven into the channel. This migration causes the electrochemical de-doping of the PEDOT and the decrease of source-drain current.

We discovered that gold as a gate contact on top of the melanin thin film does not inject or extract protons from an electrical circuit. Instead the ions in melanin are believed to form a dielectric layer at the surface of the gold, thus reducing the effective electric field. Inspecting the literature on this subject we presumed that a proton injecting/extracting gate contact, hydrogenated Palladium ($PdH_x$), would solve this problem and improve the transistor characteristics. For this I visited A/Prof. Adam Micolich, who had capabilities to make $PdH_x$ contacts and test OECT devices featuring these contacts. The aim was to bring pre-made melanin-based OECTs to UNSW, deposit Pd contacts on them, and then measure their characteristics under atmospheres with varying hydrogen and water content to look at how hydrogenation of the Pd contacts influences electrical properties.

The most significant result we obtained was a transient current measurement (Fig.1). Pd forms $PdH_x$ when exposed to $H_2$, and this can transfer protons between the contact and the underlying material. For every proton injected into the material, an electron is collected by the leads that complete the circuit.

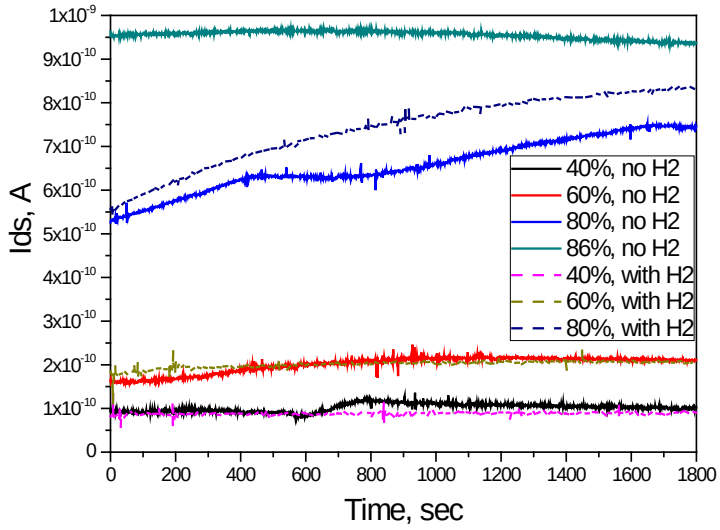



Fig.1. Channel current $I_{ds}$ vs time for a device at different relative humidity (40 - 80%) with a pure nitrogen atmosphere (no $H_2$) and a 95% nitrogen : 5% hydrogen mixture (with $H_2$) added to the chamber.

We measured the source-drain current $I_{ds}$ versus time under 100% $N_2$ atmosphere and a 95% $N_2$ : 5% $H_2$ atmosphere, with different levels of relative humidity, which we achieved by passing the gas through a water bubbler. A slight increase in current is present under the hydrogen atmosphere, as we'd expect when the Pd contacts become $PdH_x$ contacts. This result is in a good agreement with the literature [*Julia Wünsche et al. Protonic and Electronic Transport in Hydrated Thin Films of the Pigment Eumelanin. Chem. Mater. 2015, 27, 436−442*].

Further investigation of the $I_{ds}$-$V_{ds}$ characteristics for the device showed a similar behaviour: adding $H_2$ into the system gives a very slight increase in conductivity, when the change in relative humidity has a much higher impact. This is an indication that the protonic component of the steady state current in melanin increases at higher RH as expected for most proton-conducting biomaterials.

My visit to UNSW enhanced my skills in methods for vacuum deposition of Pd contacts and their hydrogenation. We can now replicate the hydrogenation setup here at UQ. The visit also forged a stronger relationship between our two groups, as discussions gave rise to ideas for future work together. I thank the Australian Nanotechnology Network very much for their support.

# Long Term Visits

ANN supports the nanotechnology community by making funding support available to **postgraduate students** and **early career researchers** (within 5 years of award of PhD degree) for travel and accommodation expenses associated with Long Term Visits to research Institutions within Australia. Up to $2,000 are provided for a maximum of three months for travel and accommodation to a location(s) within Australia.

## MR CHENGJUN ZOU FROM THE UNIVERSITY OF ADELAIDE VISIT TO RMIT UNIVERSITY

### Outcomes of Long-term Research Visit to RMIT University

Chengjun Zou, PhD Candidate

School of Electrical and Electronic Engineering, The University of Adelaide

**Abstract:**This report summarises the outcomes of my research visit to RMIT University from July 29th to November 1st 2016, with support from the long-term visit funding by the Australian Nanotechnology Network (ANN). The major outcomes include receiving trainings on advanced micro/nano-fabrications, fabrication of metasurface samples, and building up new collaborations.

From July 29th to November 1st 2016, I visited the Functional Materials and Microsystems (FMM) Research Group of RMIT University with support from the long-term visit funding provided by the Australian Nanotechnology Network (ANN). I would like to thank the ANN for this support, as this research visit has been very fruitful. The outcomes of this visit are summarised in the following.

### Training on micro-/nano-fabrication

A main purpose of this visit was to receive training and accumulate understanding on diff ent micro/nano-fabrication techniques. At RMIT University, I have been exposed to several micro-/nano-fabrication processes including spin-coating, UV-photolithography, electron-beam evaporation deposition, dry-etching, atomic layer deposition, and electron-beam lithography (EBL). With the help from members of the FMM, I received training and accumulated hands- on experience on photolithography and EBL. The training sessions were mainly taken at the Micro/Nano Research Facilities (MNRF) of RMIT University, and at the Melbourne Centre of Nanofabrication (MCN). On average, every week I worked two or three times in the clean rooms of MNRF. As a result of this training, I understand the principles, general procedures, advantages and disadvantages of these commonly used micro/nano-fabrication methods, and I am able to select the suitable methods for my nanostructure designs.

### Sample fabrication

### 1.1 Radiation cooling metasurface

A major outcome of this visit is that my metasurface design for realising the functionality of radiation cooling [1] has been successfully fabricated, with the design and fabricated sample shown in Fig. 1. The aim of the design is to have a broadband high absorption from 8 to 13 μm, with low absorption at all other wavelengths. This absorption band matches the major atmospheric transmission window in the mid-infrared (mid-IR) range. According to the Kirchhoff law of thermal radiation [2], the angular and frequency-dependent absorptivity of an object equals to its angular and frequency-dependent emissivity at thermal equilibrium [3]. There- fore, by maximising the absorption (which is also thermal emission) at the mid-IR atmospheric window, the design can potentially cool its temperature to a few or tens of degrees lower than the ambient environment temperature at thermal equilibrium.

Figure 1(b) presents the image of the fabricated sample. The sample was fabricated by etching a phosphorous-doped silicon wafer, which was then coated with a thin silver layer.

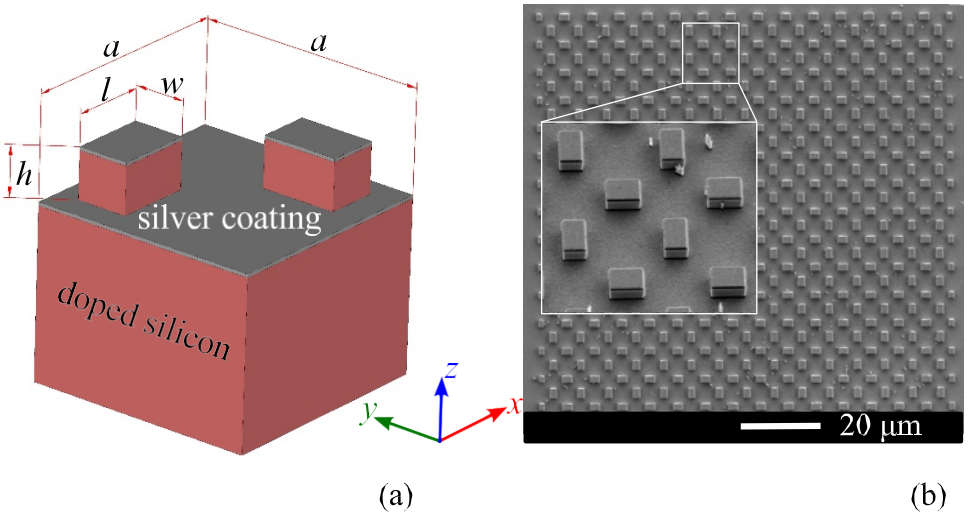



**Figure 1:** Radiation cooling metasurface. (a) The designed unit-cell of the radiation cooling metasur- face is shown with parameters $a = 6.9$ μm, $l = 2.3$ μm, $w = 1.55$ μm, and $h = 1.5$ μm. (b) Scanning electron micrograph of the fabricated sample.

The power absorptivity at IR frequencies of the fabricated sample was measured with an IR Fouriertransform infrared microscopy (FTIR). The excitation was given at oblique angles from 15° to 30°. Figure 2 presents the measurement result, with the simulated result and the atmo- spheric transmission spectrum shown as comparisons. In general, the measured result shows a good matching with the simulation. The large diff below 6.9 μm (shaded by light green) is caused by power loss via diff as higher-order diff ions occurred when the wavelength is smaller than the unit-cell periodicity. The measured result is used for analysing the radiation cooling efficiency, which has shown a good cooling performance (results not presented). Currently, a journal publication from this project is in preparation.

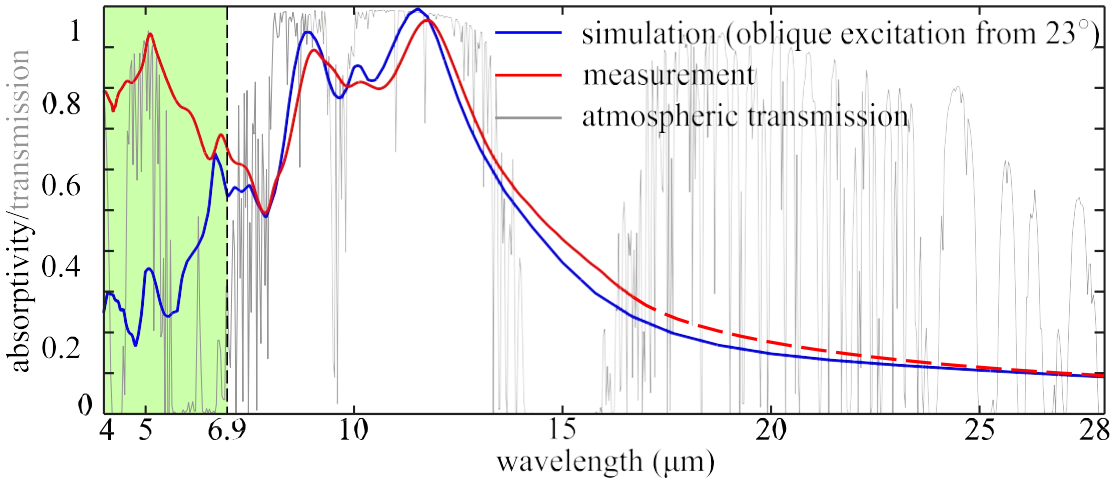



**Figure 2:** Measured power absorptivity (emissivity) of the radiation cooling metasurface. The blue curve shows the simulated power absorptivity under oblique incident excitations. The red solid line presents the measured power absorptivity, while the red dashed line is the extrapolated power ab- sorptivity outside the measurement wavelength range. The grey background is the IR atmospheric transmission for comparison purpose.

### 1.2 Surface plasmon polariton launcher

My designs of unidirectional surface plasmon polariton (SPP) launchers [4] based on nano- scale dielectric resonators on metallic surfaces are still in the process of fabrication. Due to the limited facility time-slots availability, my collaborators and I were not able to complete the fabrication within this research visit. However, further optical characterisation of this design has been arranged and we are ready for measurement once the samples are completed. The sample is expected to be completed in early 2017.

## New Collaborations

During this visit, I had the chances to build up new collaborations and interactions with researchers from RMIT University as well as other universities in Melbourne. Particularly, I would like to mention the following two collaborations. Firstly, I made acquaintance with with the Distinguished Prof. Arnan Mitchell and his group at RMIT University. We conducted a deep discussion on integrating nano-scale dielectric resonators with silicon-on-insulator (SOI) platforms, and decided to initiate a project on photonic/phononic crystal structure based on certain dielectric materials and SOI platforms. The discussion is still on-going. Another new and important collaboration is with Distinguished Prof. Min Gu and his group at RMIT University. We agreed to collaborate on the project of the radiation cooling metasurface. To be specific, Prof. Gu's group conducted the optical characterisation of this design, with some of the results being presented in Fig. 2. We are in collaboration for preparing a journal publication at this moment.

## Summary

In summary, this research visit to RMIT University has been very successful. I received hands- on trainings of several important micro/nano-fabrication methods and now have a deeper knowl- edge on the principles and limitations of these methods. A radiation cooling metasurface has been successfully fabricated and measured, which is currently in preparation for a journal pub- lication. The SPP launcher sample is also expected to be complete in early 2017. I also built up new collaborations with research groups of RMIT University. Moreover, our original col- laboration with FMM has also been deepened. Finally, I would like to thank the support from ANN for this visit.

## References

[1] Hossain, M. and Gu, M. Radiative cooling: Principles, progress, and potentials, *Advanced Science*, **3**, p. 1500360, 2016.

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*Nature Photonics*, **3**(11), pp. 658–661, 2009.

[4] Liu, Y. Palomba, S. Park, Y. Zentgraf, T. Yin, X. and Zhang, X. Compact magnetic antennas for directional excitation of surface plasmons, *Nano Letters*, **12**(9), pp. 4853– 4858, 2012.

# LONG TERM VISITS

## MR EDWARD JIANG FROM THE UNIVERSITY OF QUEENSLAND VISIT TO DEAKIN UNIVERSITY

**Destination: Deakin University, Institute of Frontier Materials, Carbon Nexus, Geelong Victoria**

**Travel dates: June 7 - November 7th 2016**

The primary aim of my visit to the Institute of Frontier Materials (IFM) at Deakin University was to be able to wet-spin new carbon fibre precursors produced from composites of polyacrylonitrile (PAN) and nanocellulose derived from Australian spinifex grass. From earlier work at the University of Queensland, the spinifex nanocellulose was found to enhance the carbonisation efficiency in electrospun composites. So we wanted to determine whether this is also the case for a wet spun carbon fibre, and study its effect on mechanical performance of a carbon fibre. This is important because high strength, ultra-lightweight carbon fibre and their composites are significantly limited in their applications due to the exceedingly high cost associated with the high processing energy consumption and a petroleum-derived PAN precursor.

Dr. Minoo Naebe's composites group at CarbonNexus/IFM have developed in-house lab-scale wet-spinning equipment which allows for the production of both single and multifilament fibres with control over processing speeds and temperatures. By accessing these capabilities at Deakin University, as well as CarbonNexus' industry-modelled single tow carbonisation line and fibre characterisation tools, I was able to spin new carbon fibre precursors containing spinifex nanocellulose, and carbonise and characterise the fibres.

In this work, I focussed on trying to answer questions relating to the effect of the aspect ratio of the nanofiller by comparing several types of nanocellulose fillers in a PAN composite fibre. These included (in order of increasing aspect ratio) cellulose nanocrystals from cotton, cellulose nanocrystals from spinifex, and nanofibrillated cellulose from spinifex. The mechanical performance of each type of fibre was then compared against a standard without a cellulose filler. After spending 3 months optimising the wet spinning processing parameters and running initial trials, all the new composite fibre precursors were successfully produced of sufficient quantity and consistency. It was observed that the presence of nanocellulose significantly affects the tensile strength and stretchability of the PAN fibre, and that this effect may be related to the aspect ratio.

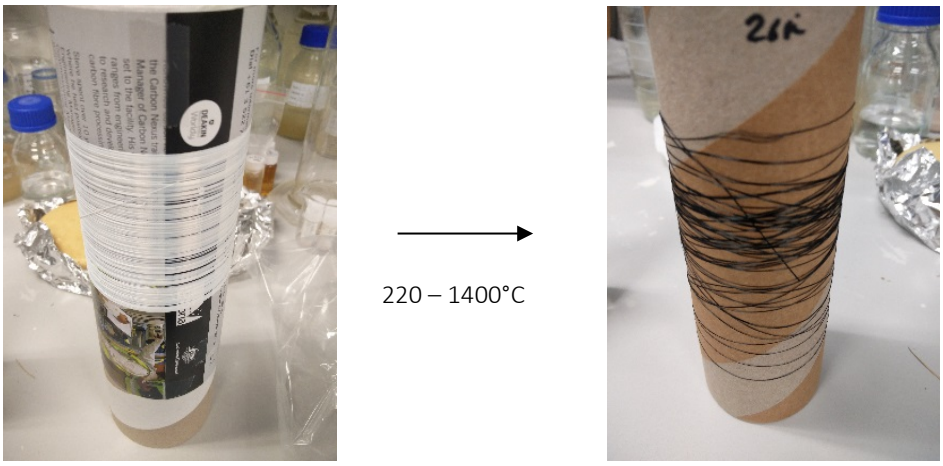


**Figure 1**. Composite precursors of polyacrylonitrile and Australian spinifex nanofibrillated cellulose, and resulting carbon fibre.

The fibres were produced in a large enough quantity to allow for thermal processing on the CarbonNexus' single tow fibre processing line (Figure 1). These fibres were 'stabilised' by passing them through a series of 4 ovens with increasing temperature ranging between 200-300°C, under tightly controlled temperature, air flow, speeds, and tensions. This produces oxidised composite fibres that are industrially-relevant, which is vastly different to how research fibres are typically processed in the lab using conventional tube furnaces where the only variable being controlled is temperature. The fibres are currently undergoing further carbonisation at 1400°C and mechanical testing, however some of the fibres saw fusion of filaments, which were caused by excess heat produced during the highly exothermic reactions that occur during stabilisation.

The next step will require me to carry out chemical and thermal analyses on the fibres to gain a better understanding of the thermochemical transformation effects the presence of the various forms of nanocellulose has on the PAN precursors, as well as help answer important fundamental questions about the chemical mechanisms for the transformation of organic matter into graphitic carbon. These results will form the basis for two upcoming publications and a conference talk at the 2017 Carbon fibres future directions conference.

I would like to thank the ANN for providing the funding for this enriching 5 month trip to Deakin University. From this trip, I feel I have grown significantly as a researcher having learnt a lot about the nuances of fibre characterisation and processing techniques that are not available elsewhere. I have also gained a greater appreciation of the stabilisation and carbonisation processes for polymer fibres from an industrial perspective and how this vastly differs from current research approaches. Outside of the lab, I have also benefited from the development of new networks with expert fibre researchers, academics, and industry visitors at the IFM, of which several new collaborative projects are currently in discussions. Finally, I would also like to thank Dr. Minoo Naebe and the composites group at CarbonNexus, who have been exceedingly accommodating and supportive during this 5 month stay.

# 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 MITCHELL NOTHLING FROM THE UNIVERSITY OF MELBOURNE VISIT TO THE UNIVERSITY OF CALIFORNIA, SANTA BARBARA

ANN Overseas Travel Fellowship 2015 – Award Outcomes Report

Mitchell D. Nothling

With the generous support of an Australian Nanotechnology Network Overseas Travel Fellowship, I have recently completed a six-month research visit at the University of California Santa Barbara (UCSB). The aim of my visit was to extend my current PhD research by leveraging the polymer engineering and nanotechnology expertise of Prof Craig Hawker and his team within the Material's Research Laboratory at UCSB. Please find the outcomes of my overseas travel summarized below according to the goals outlined in my fellowship application.

### Major outcomes of overseas visit

The detergent industry is one of the world's largest consumer industries with annual sales in excess of A$60 billion. The addition of enzymes into detergent formulations is now common practice, and the enzyme component of modern detergents is the key to their effectiveness for degrading organic stains. However, the application of these detergents is limited due to the low stability, limited operating temperature and high cost of the enzyme components. My research is developing synthetic catalytic surfactants that mimic the chemistry of enzymes for application in the detergent industry. My synthetic enzymes will aim to achieve the breakdown of organic material that makes the natural enzyme so effective in detergents, while expanding the operating range of these products.

Specifically, my work is aimed at mimicking the functional core of enzymes- the active site- to yield a synthetic organic catalyst. This new advance applies a nanotechnology approach to prepare and assemble enzyme-inspired catalysts, an entirely new technique in this field. Preliminary results around the performance of these new materials have been promising, forming the basis of several patents with the global consumer goods company Unilever. The work has the potential to deliver significant economic and environmental advantages to other industries that employ enzymes, and may pave the way for future research in enzyme mimicry.

The project has been truly interdisciplinary in nature, promoting collaboration between chemists, microbiologist, engineers and materials scientists. The materials engineering department at the University of California- Santa Barbara is a world- leading institute in my field of research and it's director, Professor Craig Hawker, is an international authority in this field. Professor Hawker personally invited me to work with his team to extend my current work with enzyme mimics.

By leveraging the polymer engineering expertise of Professor Hawker and the UCSB materials research team, I have been successful in optimizing my new catalysts for commercial application. This has been further supported through close interaction with the UCSB industry partner Dow Chemicals Institute, as well as our commercial collaboration with Unilever. I was able to access the world-class expertise and infrastructure at UCSB, providing an outstanding opportunity for both my project and my future career.

During my research visit at UCSB, I have achieved:

The formation of a rigid self-assembled polymer structure that incorporates my artificial enzyme core. This was achieved by liaising with the materials engineering expertise at UCSB to design, synthesize and evaluate new catalytic resin particles.

I had the chance to work closely with Professor Hawker and his team, designing tertiary structures for the delivery of my artificial enzyme core to a detergent application. Professor Hawker is considered one of the world's top 50 living scientists and is a recognized authority on polymer synthesis and self-assembly. He is a fellow of the American Chemical Society and has been cited over 37,000 times for his pioneering work in the field of polymer science and materials engineering. As well as this, the infrastructure available at UCSB is world-class, which gave me the chance to undertake the full range of research with my new materials, from synthesis to evaluation.

Close collaboration with the industry partners at UCSB to optimize the synthetic procedure and viability of my new catalysts for a commercial setting. These materials can now be made cheaply, quickly and from readily available starting materials; a significant step toward implementing these new catalysts in an industrial setting.

Considering the end use of my new materials was of paramount importance to me during each stage of the project. I interacted closely with the industry partners at UCSB (Dow Chemicals Institute, Mitsubishi Chemicals) to determine the characteristics of my new technology that could make it industrially viable. The techniques that I have learned from my engagement with these organizations are now being used to guide the final stages of my project, greatly enhancing the feasibility of the materials that I have produced. This experience will also serve me well as I move into my career in research back home in Australia.

The development of technical skills in polymer engineering, organic synthesis self-assembly of materials, as well as scale-up and scientific presentation in one of the world's leading polymer science research groups.

A number of researchers that I met at UCSB are world experts in the fields of particle self-assembly and polymer engineering. I was particularly excited to work with Professor Hawker. As a pioneer and world authority in the scientific fields associated with my work, my collaboration with him was extremely beneficial for my project and personal development. These emerging fields of nanotechnology have huge potential over the coming decades and suitably trained engineers will be a significant asset for the Australian scientific community. I feel that the personal and professional growth afforded by this opportunity has been extremely beneficial to both my PhD project and my furture career. As a result of my overseas visit, I have also now established ongoing collaborations with several other groups across the USA, Germany, South Korea and the UK.

### Specific outputs of the overseas visit

The specific outputs of my research visit have all acknowledged the generous support of ANN and include:

An original manuscript that has recently been accepted for publication by the journal Chem (a general-chemistry sister journal to Cell), entitled “Simple design of an enzyme inspired supported catalyst based on a catalytic triad”. Publication in print is expected mid-year.

Results presented as an oral presentation at the Fall 2016 meeting of the American Chemical Society in San Diego, CA. Further results presented as an oral presentation at the 36th Australasian Polymer Symposium in Lorne, VIC.

Further results presented as an oral presentation at the inaugural Emerging Energy Technologies Summit and Exhibition in Melbourne, VIC. I was the winner of the best student presentation award for this talk.

I appeared as a guest on a local Melbourne radio station’s (3-RRR) weekly science program, “Einstein-a-go-go” to discuss my project.

A finalist appearance in the University of Melbourne 3-minute thesis completion, summarizing the work conducted during my overseas visit.

Overall the research visit has been incredibly beneficial to me completing a successful PhD project and growing as an independent researcher. I feel that the skills that I have developed during my overseas stay will position me perfectly for my career in research leadership and enable me to contribute significantly within my industry.

Personally, working and living in the USA for this period has been a truly memorable experience and I am extremely grateful to the Australian Nanotechnology Network for their generous support.

# OVERSEAS TRAVEL FELLOWSHIPS

## MR. MD SHARAFAT HOSSAIN FROM THE UNIVERSITY OF MELBOURNE VISIT TO THE UNIVERSITY OF CALIFORNIA, BERKELEY, USA

**Research work conducted as a visiting student at Purdue University by**

**Md Sharafat Hossain PhD Student, University of Melbourne**

**Supported By: Australian Nanotechnology Network Fellowship**

**Robert Bage Memorial Scholarship**

**Supervised by: Rajib Rahman Research Professor Purdue University, IN, USA**

**Je-Hyeong Bahk, Assistant Professor, University of Cincinnati, OH, USA**

### Introduction:

This report is a summary of the research work performed at Purdue University and supported by ANN and Robert Bage memorial scholarship. In this trip, I have worked on three correlated topics which aligns perfectly with my PhD research. As my PhD work is on thermoelectric characterization of graphene nano-ribbons, knowledge about other two-dimensional materials will enable be to extend my work. So, in the first month of my trip, I learned about exfoliating two-dimensional materials beyond graphene. This experience will enable me to apply similar approach of thermoelectric measurement to other two-dimensional materials such as $MoS_2$ and $WSe_2$. Another emerging topic related to two-dimensional materials are vertically stacked heterostructure. In the next one and half months, I worked on modelling vertical transport of 2-D materials. This involved learning quantum mechanical simulation tool NEMO5 which is a multiscale Multiphysics nanoelectronics modelling tool. I was able to model a previously observed experimental results. Finally, I worked on modelling the thermoelectric performance of organic materials which has become a promising candidate for future thermoelectric industry.

| Duration | Work Done | Explanation |
|---|---|---|
| 4 weeks | Getting lab training Learning exfoliation techniques Characterization | Phase 1 |
| 6 weeks | Learning NEMO5 Literature review Simulations Summarizing results | Phase 2 |
| 4 weeks | Literature review on organic thermoelectrics Implementing TE transport | Phase 3 |

In the rest of the report I have provided a timeline of the activities performed in the trip. Then I have summarized the key points of the research performed on each topic

### Timeline:

#### Phase 1

#### Exfoliation of two-dimensional Materials

Currently our group has experience with graphene. We have several publications investigating the thermoelectric properties of GNR. However, we lack the expertise in working with 2-D materials beyond graphene. In this phase of my travel I spend a couple of weeks learning about the exfoliation of 2-D materials beyond graphene, like MoS2

and WeS2. Even though the exfoliation technique is like graphene, there are some subtle difference that are crucial for successful exfoliation, which I learned from doing the exfoliation. Some of the issues are:

- The yield of single layer MoS2 WeS2 and Phosphorene are much less then single layer graphene. Also, the flake size is much small then that on graphene. I also realized that the flake size depends on how many times the tape has been folded.
- To get good contrast in optical microscope, the flake should be on 90nm SiO2. This is different from Graphene where the optimal SiO2 layer thickness is 300nm.
- MoS2 and WSe2 is more reactive to the environment than graphene. On the otherhand, Phsophorene is extremely reacrtive. So the processing after exfoliation is different. Then should be covered with resist like PMMA to avoid contact with experiment and should be stored in inert environment.

Below are the images of some of the exfoliated WSe2 on SiO2 substrate:

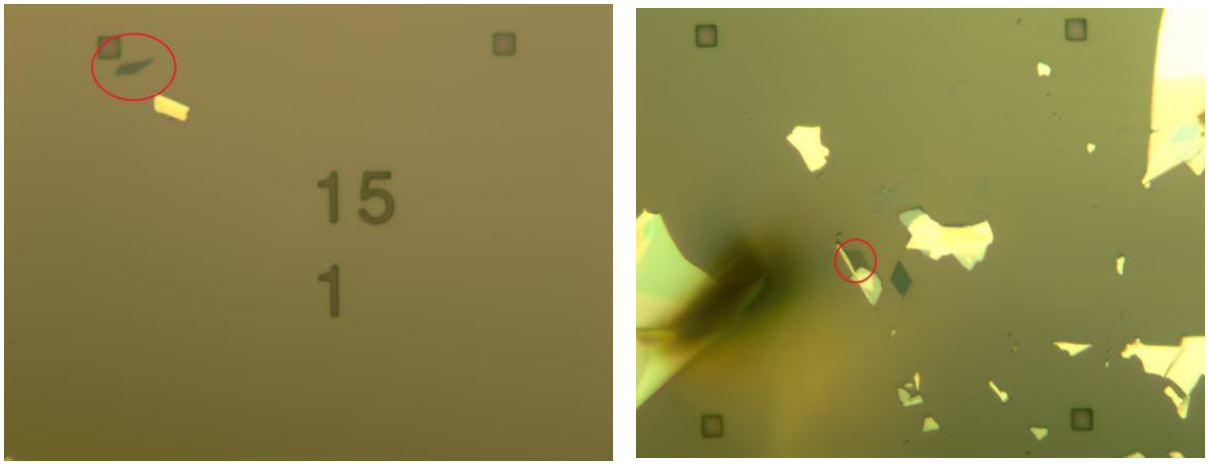


*Figure 1: Optical image of exfoliated WSe2. The red circled regions indicate single layer WeS2. The brighter patch is multilayer WSe2. Unlike graphene, we can see small yield of single layer WSe2*

## Modelling Vertical transport

### Introduction:

Vertical stacking of two-dimensional materials has recently become popular due to the unique electronic and optical properties they offer [1-3]. Several theoretical and experimental work has been carried out to understand the unique physics of these structures [4-6]. Resonant tunnelling behaviour is one of the key characteristics of these devices which can be used in a range of application including novel memories, multi-valued logic, inductor-free compact oscillators [7].

Graphene-hBN-Graphene (Gr-hBN-Gr) is one of the first experimentally observed vertically stacked devices [3]. Graphene and hBN has closely matched lattice structure which makes them suitable candidate for vertical stacking. Britnell et al have experimentally investigated Gr-hBN-Gr structure and observed resonant tunnelling behaviour in these structures [8]. Since then several group have developed theoretical model to understand and investigate the effects of physical parameters like device geometry, lattice mismatch and rotation angle[4, 9-11]. Even though these models have been successful in simulating several aspects of experimental observations neither of them could match the current level of the experimental measurement[4]. Moreover, none of them could account for the trend in the background current of the system. In this work, we address these issues by modelling the vertical transport in Gr-hBN-Gr structure using atomistic quantum transport simulation based on semi-empirical tight binding approach. By using a linear combination of the well-known coupling parameters between C-B and C-N, we could accurately model the current level as well as the trend in background current. Moreover, we varied the number of hBN layers and established an empirical formula for dependence of current on the number of hBN layers. Finally, we determined the relation of Peak-to-Valley (PVR) ratio with the number of hBN layers.

## Method:

The Hamiltonian of both graphene and hBN has been represented using Pz nearest neighbour tight- binding model. We used the previously established parameter to model intralayer transport[12]. To model the vertical transport, we used a linear combination of the coupling parameter of C-B and C-N. All the transport properties have been simulated by first evaluating the poisson equation to get the potential which was then passed into quantum transport boundary method (QTBM) in the multi-scale Multiphysics Nanoelectronic modelling tool NEMO5 [13]. To validate our one pass method, we compared our transport calculation with self-consistent Poisson-QTBM method for a few bias points and found significant similarity.

### RESULTS AND DISCUSSION:

Figure 1 shows our simulated structure with a hBN layer sandwiched between two graphene layers.

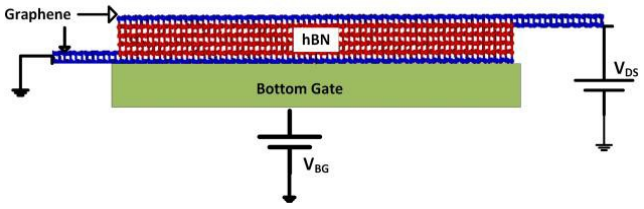


Figure 1: Schematic of the simulated device structure

Our overlap region is 25nm with source and drain extension of 15nm. Our back gate is underneath the overlap region with effective oxide thickness of 0.5nm. We have considered doping of 1e13 in the source and drain graphene region. Figure 2a shows the id-vd curve for different gate voltage. We can see prominent negative differential resistance (NDR) peak whose value and position shifts with gate voltage. The NDR results from the alignment of the Dirac cones of the top and bottom layer which enables momentum conserved tunnelling. This is consistent with the experiment and previous theoretical models [4, 8]. Fig 2b shows the matching potential of the top and bottom layer where we observed the peak current. This results in high transmission as shown in fig 2c.

Figure 2d shows that a slight mismatch is the potential of the two layer results in drastic decrease in transmission (Fig 2e).

Fig 3(a-d) shows how the number of hBN layers effect the current. We observe that the current reduces exponentially with the number of hBN layers which is consistent with the tunnelling mode of transport [14]. For smaller bias voltage, we observe an exponential id-vd dependence. However, for |Vd|>0.8V the current becomes linear with bias voltage. To develop a model for layer dependent transport, we have formulated an empirical piecewise model

$$I_{DS} = \begin{cases} Ae^{cV_{DS}} \times e^{-3.3n}, & |V_{DS}| < 0.8 \\ B \times V_{DS} e^{-3.3n}, & |V_{DS}| \geq 0.8 \end{cases}$$

Where A, B and c are constants to fit the simulation results and n is the number of layers. As we can see the current has an exponential dependence on the number of layer ~exp(-3.3n). This is consistent with DFT based previous where it is shown that transmission has a ~exp(-3.4n) dependence on the number of layer. Figure 3e show the simulation result for 1-4 layers of hBN. Our empirical model matches with the simulation for different layers. Importantly, we used our model to predict the transport for barrier of 5-hBN layers. Our model successfully predicted the experimental results obtained by Britnell et al. [8] as shown in figure 3e. It should be noted that we observed secondary peak around the main one which can be attributed to the lateral maxima of the spectrum of the rectangular well-like confining potential [5]

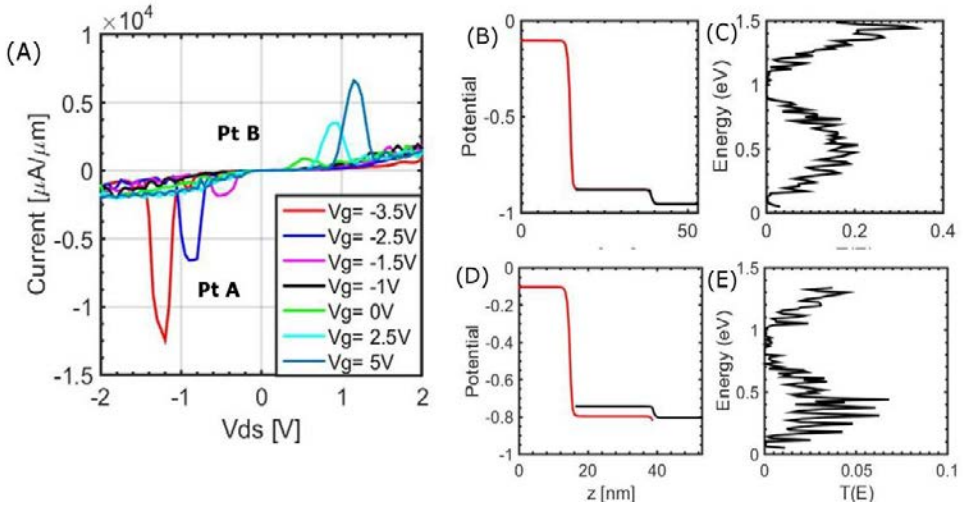


*Figure 2: (A) Id-Vg curve for different gate voltage of a Gr-2Layer hBN-Gr structure. We can see the NDR peaks. (B)-(C) Alignment of the potential of top and bottom layer where the NDR peak is observed and the corresponding transmission* transmission.

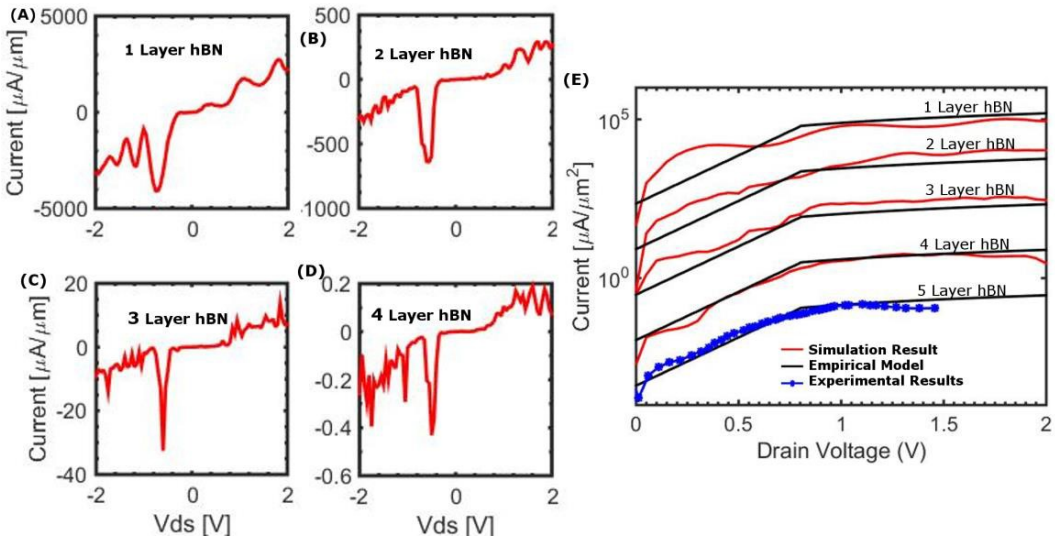


*Figure 3: (A-D) Current vs drain voltage for different barrier thickness starting from one layer hBN to four layer hBN. (E) Current vs drain voltage is compared for simulation, empirical model and experimental results. Our empirical model could accurately explain the experimental results*

Next, we analysis the dependence of the NDR peak on the gate voltage and number of hBN barrier layers. Gate voltage shift the potential of the bottom layer and drain voltage shift the potential of the top layer. If higher bias voltage is required to align the Dirac cones of both the layers, it results in higher tunnel current flows due to the availability of more states. This is reflected in the linear relation of the PVR with gate voltage as shown in figure 4a. However, the slope is much higher in the negative gate bias regime compared to the positive gate bias regime. This is because it takes higher drain voltage to align the Dirac cones when the gate bias is negative resulting in more current. On the other hand, PVR increases drastically with the number of layers. Moreover, the width of the peak decreased with the number of layers. This can be understood by the uncertainty of the wavefunction (??). It should be mentioned that our PVR[15] value is much higher than experimentally observed one. This is because we didn't take into account several scattering mechanisms like electron-phonon scattering and the effect of the substrate. These non-idealities can destroy the coherence of the wave function reducing the amount of tunnelling current.

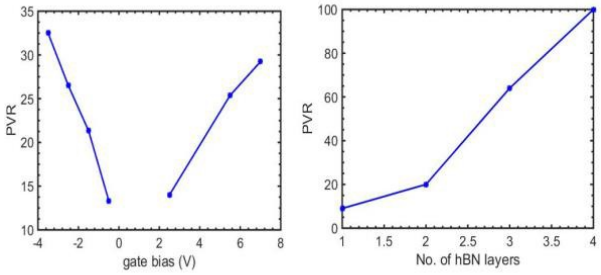


*Figure 4: (A) Peak to valley ratio of the NDR peak for different gate bias. (B) PVR for different number of hBN barrier layers*

## Conclusion:

We have modelled vertical tunnelling transport in Gr-hBN-Gr heterostructure by using a linear combination of vertical coupling parameters of the constituent atoms. Our simulation results are successful in modelling the trend of the background current as well as the current levels from previous experiments. This technique can be extended to vertical transport in other two-dimensional materials system. Moreover, prediction about electronic properties can be made for various possibilities of vertical stacking using this method

Phase 3

## Modelling organic plymer

I have been working on experimentally quantifying the thermoelectric performance of organic materials. However, a proper model to explain the experimental results were lacking. In this phase of my travel I worked with Prof. Je-Hyeong Bahk to develop a model that can explain our experimental works.

There are several models that explain transport in organic materials and few that take into account thermoelectric effects. In this work, first, I went through literature to summarize all the techniques for thermoelectric modelling of organic semiconductor. Next, I discussed with my supervisor about the techniques and we chose the best technique that is suitable for our case. After this, I implemented the model to replicate some known work. Currently I am working on using the model to explain my experimental work.

## Modelling Techniques:

The transport in organic material is significantly different than single crystal semi-conductor. The absence of long range order leads to the localization of charge carriers. As a result charge carrier transport are characterized by hopping between localized states of Gaussian or exponential density of states. Three parameters become important in this mode of transport: 1) Localization Length(α) which represents the spread of the wave function. 2) intrinsic attempt-to-jump rate (v0) which can be either Phonon assisted hopping or Fluctuation induced tunneling 3) Degree of energetic disorder (aDOS): quantified by the standard deviation (aDOS) of the carrier density of states (DOS).

## Gunho Kim's Model:

In this model[16], Miller-Abraham hopping model is used to get the transition rate. To get the average distance a carrier must hop, percolation threshold parameter is utilized.

Using a known experimental result[17], they used this model to extract the above mentioned three parameters. dS/d(ln(n)) is used to extract αDOS from slope fit, then α is extracted from subsequent fit. Finally vo is determined by a fit to sigma data.

This model predicted that localization length can be spread over 2-3 molecular distance. It also states that S is strongly affected by the shape of the carrier DOS (e.g., aDOS) and localization length. It is not, however, not effected by attempt to jump v0.

**Model based on percolation theory:**

This model[18] is based on percolation theory and hopping transport. It explained the features of transport approaching disorder free transport. To match experiment following fitting parameters used:

, Nt (number of states/vol) εs, εf0, Ci, α (inverse localization length). S vs carrier density with several temperatures is fitted using this model.

**Stedman's Model**

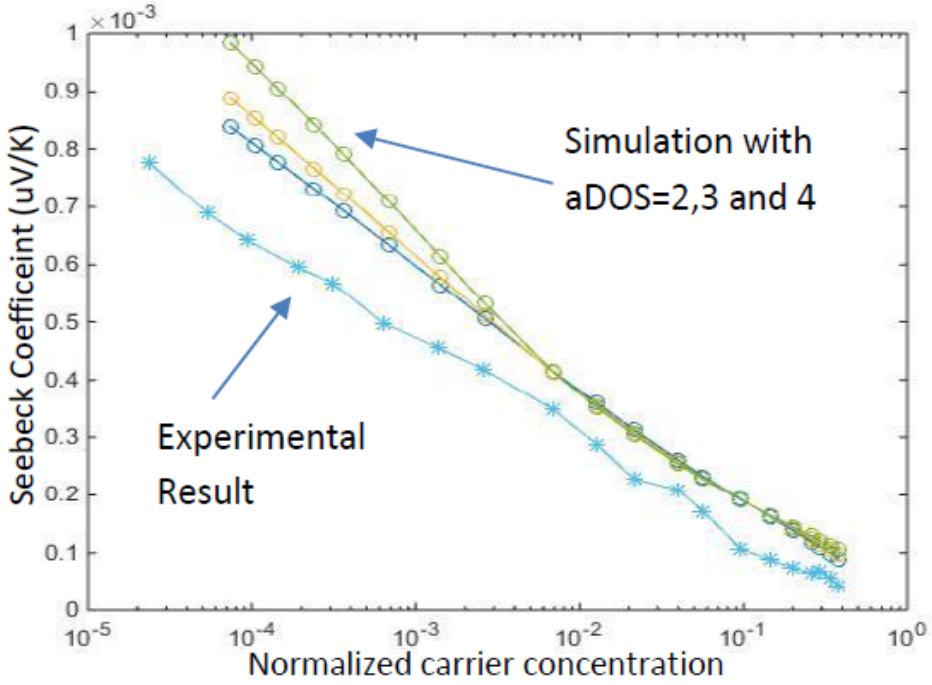


*Figure : Seebeck coefficient vs normalized carrier concentration for varying aDOS. We can see how the slope changes with aDOS. Experimental data is also presented in the same plot.*

This model [19] is based on fluctuation induced tunnelling between large metallic regions. Transport in the direction of applied field will be modified by the local fluctuating field. Any quantity depending on thermally fluctuating field will be averaged by a Boltzmann like function. Then, Landaur expression used for electric current and electronic heat current which is averaged over fluctuating field. Parabolic barrier used and expression for tunnelling probability is adopted from literature. This model is used to fit several experimental results. There are four fitting parameter: width, cross section area, barrier height and effective mass.

Mobility edge model:

In this model[20], mobility edge model is used to extract the thermoelectric parameters. The ME model assumes that there is a defined energy (the mobility edge) in the DOS that separates mobile states from localized states. Trapped carriers become temporarily mobile by thermal excitation to the mobile states. The mobility edge, E=0, was defined at the top of the band-like states. Holes at energies below the mobility edge E0 are mobile and assumed to have a constant mobility μ0, while holes located at energies above the mobility edge have zero mobility

A density of states distribution that fits the whole set of temperature dependent data is found by successive iterations using Ntot (the total concentration of tail state), Eb (the width (in eV) of the exponential tail), and μ0 as fitting parameters.

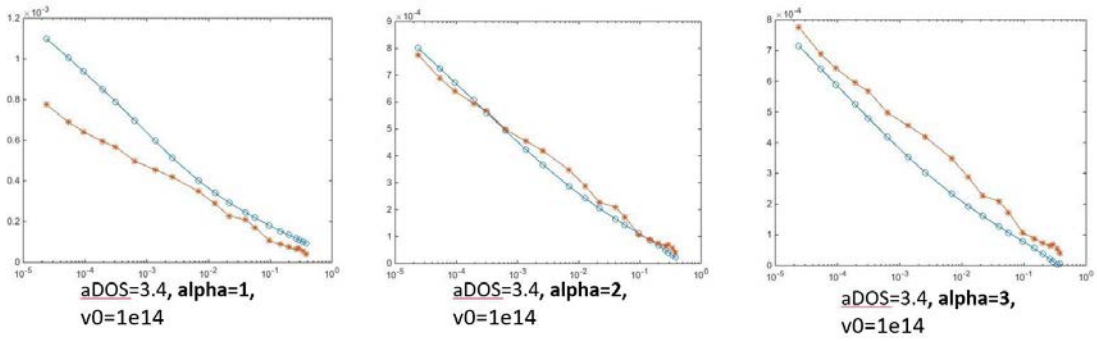


*Figure : Blue curve is the simulation results while the red one is the experimental results. From left to right we can see how change in alpha shift the results in vertical direction. Other parameters are kept constant*

## Implementation:

After analysing the modelling techniques, we took into account several metrics like ease to implement, number of fitting parameters used and reproducibility of experimental results, before choosing one. Gunho kim's model with only three fitting parameters and excellent experimental reproducibility was a perfect fit.

After choosing the model I tried to explain a known experimental result using this model. First, I varied the density od states aDOS and observed its effect. Fig shows how the value of the aDOS alters the slope of the S vs carrier concentration curve. By fitting the slope with the experimental results we found aDOS=2.2 for this set of experiment. This is close to the reported value.

Next, I varied the localization length, which shifts the S vs n curve in the vertical direction. By fitting with the experimental values, the extracted localization length was 2.1a, where a is molecular distance. Figure shows the experimental results with model using best fit parameters.

Finally, to extract the value of hopping rate I used the conductivity data. The values of aDOS and alpha extracted by fitting the Seebeck co-efficient is used. Figure shows the experimental results along with the modelling. My extracted hooping rate is 1e14 which matched with previous report.

## Conclusion

Above validation confirms that my implementation of the model is correct. Next step is to explain my experimental results using the model. Experimental work is underway.

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# OVERSEAS TRAVEL FELLOWSHIPS

## DR DANIEL SANDO FROM THE UNIVERSITY OF NEW SOUTH WALES VISIT TO THE INSTITUTE OF PHYSICS AT THE TAIWANESE NATIONAL LABORATORY.

**ANN Travel Report – Daniel Sando (Travel to Taiwan and France, BiFeO3/CaMnO3 superlattices and Bi57FeO3 (110) oriented films for magnetic structure determination**)

**PURPOSE OF THE VISIT**

The aim of this visit was primarily to make use of the pulsed laser deposition (PLD) capabilities of the "Atomic Foundry of Complex Oxides" laboratory at the Institute of Physics, Academia Sinica (Taiwanese National Lab), Taipei, Taiwan. The sophisticated thin film growth system in this lab allows layer-by-layer control of the growth of epitaxial oxides [with in-situ growth monitoring using reflection high energy electron diffraction (RHEED)]. Such a capability is crucial for exploring interfacial effects in so-called superlattices (SLs), where two materials are artificially combined in periodic patterns. For this study we chose multiferroic BiFeO3 (BFO) and Mott insulator CaMnO3 (CMO) for the two materials.

Further, by combining the travel with a previously-organised trip to two laboratories in France [Unité Mixte de Physique CNRS/Thales - UMPhi (near Paris), and Groupe de Physique des Matériaux - GPM (Rouen)], I was able to initiate a second project which focused on exploring the thickness-dependent magnetic order of multiferroic BiFeO3 thin films. At UMPhi, I had access to a unique BiFeO3 target 100% enriched with 57Fe. Using this enriched target for the growth of epitaxial thin films allows the use of conversion electron Mössbauer spectroscopy (CEMS) to measure thin films in very short timeframes (hours, instead of weeks using nonenriched films). The GPM lab is a leader in the CEMs technique, which is crucial for measuring thin films. An important strength of using enriched films is that it becomes feasible to measure the magnetic order of ultra-thin films (~ 5 nm), which is simply impossible with traditional magnetic probes such as neutron diffraction.

**RESEARCH BACKGROUND**

Multiferroic materials, compounds which possess more than one ferroic order (e.g. ferroelectricity and magnetism) attract significant research interest, not only for their fascinating physics, but importantly for their applications potential, particularly in the field of spintronics. The discovery of the room temperature multiferroic material bismuth ferrite (BiFeO3 – BFO), and, more specifically, its integration as epitaxial thin films, has triggered intense research into developing it for practical nanoscale devices.

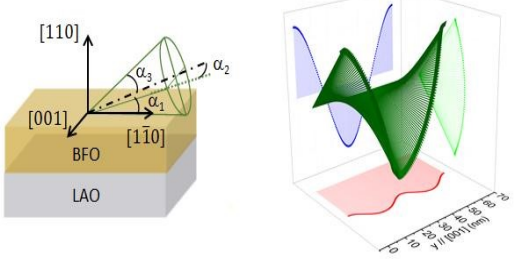
It was recently shown that epitaxial strain in (001)-oriented BFO films can be used to strongly tune the magnetic order (Sando et al., Nature Materials 2013) and optical response (Sando et al., Nature Comms 2016). An alternative research direction involves playing with the growth orientation of the films; for instance, by using (110)-oriented substrates, we can apply strongly anisotropic strain to the film. Such anisotropic strain is expected to drastically modify the spin ordering patterns. It is typically rather difficult to measure the magnetic properties of thin antiferromagnetic films since the method of choice, neutron diffraction, requires a large sample volume. With this in mind, alternative methods have to be found: e.g. Mössbauer or Raman spectroscopy. Mössbauer spectroscopy can be greatly assisted by using 57Fe enriched samples (since Mössbauer is only sensitive to the 57Fe isotope). Using a different approach entirely, a powerful method for tuning physical properties (magnetism, electronic

structure) in thin films is through so-called superlattices. By artificially combining two materials with differing magnetic order (e.g. magnetic and non-magnetic), completely new physics can arise through the interfacial interactions between the constituent materials. It was the aim of this project to explore the influence of the superlattice period of BFO/CMO (multiferroic and Mott insulator respectively) on the ferroelectric, magnetic, and optical response of 100 nm thick superlattices.

**RESEARCH FINDINGS**

The first part of the visit, at Academia Sinica, Taiwan, was fruitful with a wide range of SL structures fabricated. Using these superlattices, we have been able to investigate the interfacial effects between the CMO and BFO layers, along with the influence on the ferroelectric domain structure, and ferroelectric switching characteristics. Further optical and magnetic characterisation is in progress.

The second part of the visit, at UMPhi, entailed the fabrication of ~20 BFO thin film samples enriched with 100% 57Fe. This unique substitution allows measurement of Mössbauer spectra in a reasonable timeframe (even a 10 nm film can be measured with just a few days' counting time). Using these samples, we have been able to show evidence of a 'conic cycloid structure' in (110)-oriented BFO films (Figure 1); this project is now taking shape with theoretical input from A.K. Zvezdin (Russian Academy of Sciences), and the manuscript "Conic cycloidal order in (110)-oriented BiFeO3 films" is in preparation for submission to Physical Review Letters.




A further exciting development was the observation of a thickness-dependent antiferromagnetic (AFM) transition in ultra-thin BFO films. When BFO films are fabricated under very strong compressive strain, the AFM transition (normally ~640 K) is strongly decreased to ~380 K. It appears, based on our findings, that this transition can be further tuned to below ambient, simply by modifying the film thickness. The data. for this study are rather preliminary, but this research direction appears very promising for a high impact work.

*Figure 1. Schematic of a conic cycloidal order in a (110)-oriented BiFeO3 film*

**VISIT OUTCOMES**

This visit enabled predominantly the fabrication of a very large number of samples, which are now undergoing further analysis, such as x-ray diffraction, Mössbauer spectroscopy, optical characterization, ferroelectric measurements, and Raman spectroscopy. By making use of the specific strengths of the respective labs (RHEED-assisted PLD for superlattices at Taiwan, and the 57Fe substituted BFO at UMPhi), we have evidenced a number of interesting phenomena, such as a conic cycloidal order in BFO thin films, as well as a thickness-dependent antiferromagnetic transition temperature in ultrathin BFO films. Further beneficial outcomes from this research trip were the collaboration efforts with the three separate groups (with seminars at each laboratory, encouraging discussion and important feedback on my work), and the possibility to expand my experience base to a PLD system with superlattice capabilities, and the opportunity to learn the experimental process of Mössbauer spectroscopy, particularly involving the complex procedure of fitting a Mössbauer spectrum.

# OVERSEAS TRAVEL FELLOWSHIPS

## MR HAMISH BROWN FROM THE UNIVERSITY OF MELBOURNE VISIT TO THE UNIVERSITY OF TOKYO

Australian Nanotechnology Network Overseas Travel Fellowship Outcome

Hamish Brown

As well as being awarded the Australian Nanotechnology Network (ANN) Overseas Travel Fellowship for a visit to the Crystal Interfaces Laboratory at the University of Tokyo, Japan, I was also a recipient of the Australian Government Endeavour Fellowship. This second fellowship allowed to me extend my visit to Japan to six months in total, allowing me more time for more meaningful collaboration with the Japanese group.

The visit to Japan culminated in the publication of a paper "A new method to detect and correct sample tilt in scanning transmission electron microscopy bright-field imaging" in the journal Ultramicroscopy.

[1] Recently there has been much interest in using scanning transmission electron microscopy (STEM) to map the positions of light atoms in perovskite materials as a way of studying octahedral rotations – deformations of the atomic structure which are related to technologically important properties of these materials. This requires atomic positions to be mapped with picometer precision and is complicated by the fact that misalignments of these specimens also cause apparent shifts in the positions of these atoms by a few picometers. The paper suggest new ways to identify these mistilts in the images themselves and a way to correct these mistilts as a post-processing step if the microscope is equipped with a fast-readout electron camera, an emerging technology in the field of microscopy.

In addition to this I was involved in research looking into using new techniques for mapping electric fields at atomic resolutions in STEM to investigate atomic bonding in materials. This research is ongoing and I am continuing to collaborate with my new Japanese colleagues in my new position as post-doctoral researcher in Electron Microscopy at the School of Physics and Astronomy at Monash University, Melbourne.

My time in Japan also coincided with the 5$^{th}$ International Symposium on Advanced Microscopy and Theorectical Calculations (AMTC5) in Nagoya, and I was able to attend this conference and make a poster presentation titled "Structure retrieval in STEM using segmented detectors."

[1] Brown, H.G., Ishikawa, R., Sànchez-Santolino, G., Lugg, N.R., Shibata, N., Allen, L.J. and Ikuhara, Y. "A new method to detect and correct sample tilt in scanning transmission electron microscopy bright-field imaging", Ultramicroscopy 173 (2017) 76-83.

## MR JASON BRENKER FROM MONASH UNIVERSITY VISIT TO THE PAUL SCHERRER INSTITUTE (PSI) IN VILLIGEN SWITZERLAND

We had previously developed a series of novel, x-ray compatible microfluidic methods for encapsulating, manipulating and analysing molecules in tiny aqueous droplets. We have since refined these techniques further to enable the in-situ characterisation of chemical systems through X-Ray Absorption Spectroscopy (XAS). Working with Dr Thomas Huthwelker, Dr Katja Henzler, Dr Camelia Borca, and Mrs Jacinta Xto at the Pheonix Beamline at the Paul Sherrer Institute in Switzerland, we had abundant access to the beamline from September 1st through to December 24th 2015, and November 23rd to December 9th 2016. This allowed me to not only broaden my understanding of synchrotron and beamline operations, but I was also able to make valuable connections with researchers with whom I am continuing to collaborate.

An improved understanding of the crystallisation process, specifically the formation of prenucleation clusters, will have significant implications in a variety of research fields such as synthesis of nanoparticles, protein structure determination, formation of geological sediments and biomineralisation. The specific reaction focused on in this study was Calcium Carbonate (CaCO3) precipitation from the combination of Calcium Chloride (CaCl2) and Sodium Carbonate (NaCO3).

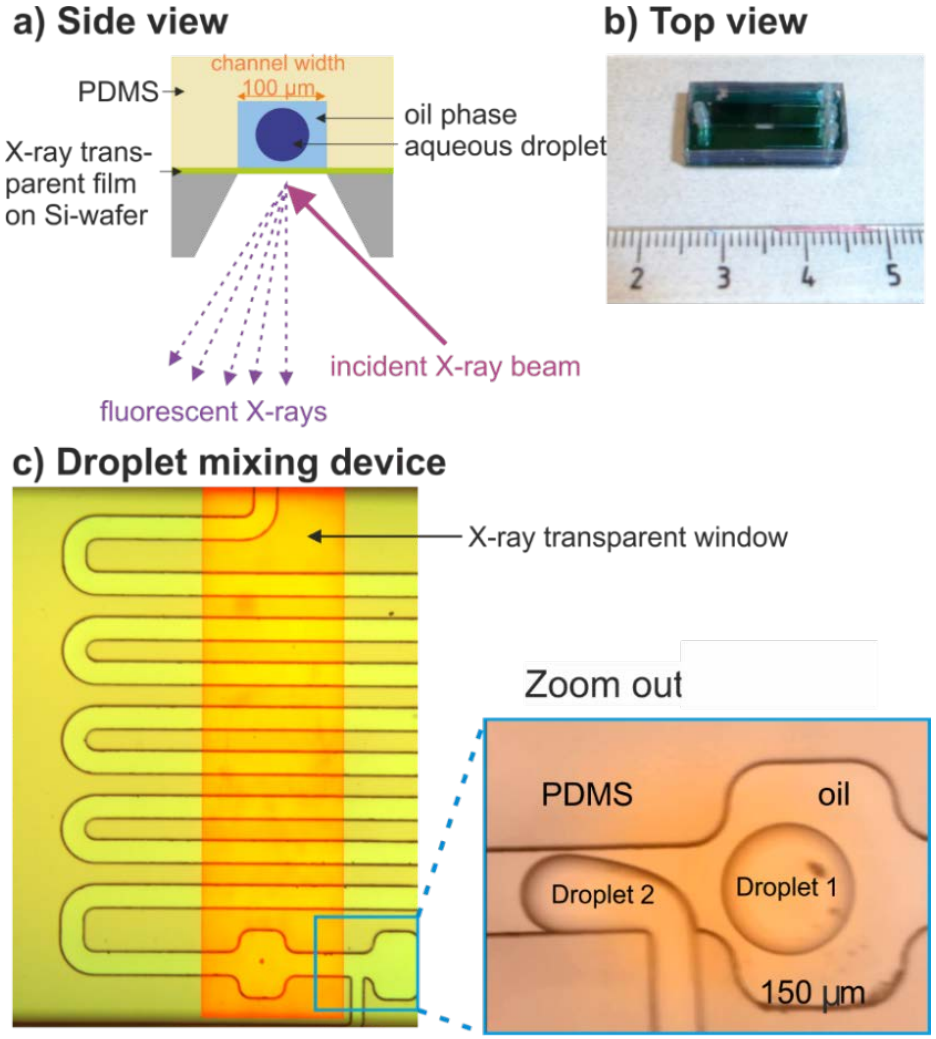



Figure 1:a) cross-sectional schematic of the microfluidic device highlighting key components. b) Top view of the microfluidic device. c) serpentine channel allowing for multiple time points to be measured with inset image showing droplet mixing regions.

Having developed a series of novel, x-ray compatible microfluidic methods for encapsulating, manipulating and analysing molecules in tiny aqueous droplets we develop these techniques further to enable in-situ characterisation of chemical systems through X-Ray Absorption Spectroscopy (XAS). An improved understanding of the crystallisation process, specifically the formation of prenucleation clusters, will have significant implications in a variety of research fields such as synthesis of nanoparticles, protein structure determination, formation of geological sediments and biomineralisation. The specific reaction focused on in this study was Calcium Carbonate ($CaCO_3$) precipitation from the combination of Calcium Chloride ($CaCl_2$) and Sodium Carbonate ($NaCO_3$).

The devices consisted of PDMS microfluidic channels bonded to silicon based chips containing ultrathin, X-ray transparent, observation windows (free standing 100-nm-thick silicon nitride, SiN, membranes shown in Fig. 1). The windows allow the incident X-rays to penetrate the channel and interact with the samples contained within aqueous droplets, essentially reaction chambers which are carried in an immiscible oil phase.

Due to the brief reaction times being probed during XAS, only a small number of photons were detected during each measurement, thus many reactions were measured in series at each time point. To demonstrate the potential of our system we used a solution of 1 M $CaCl_2$ encapsulated in aqueous droplets in a fluorinated-oil. Using a measurement time interval of 10ms a time resolved analysis generated the spectra of $CaCL_2$ represented in Figure 2.

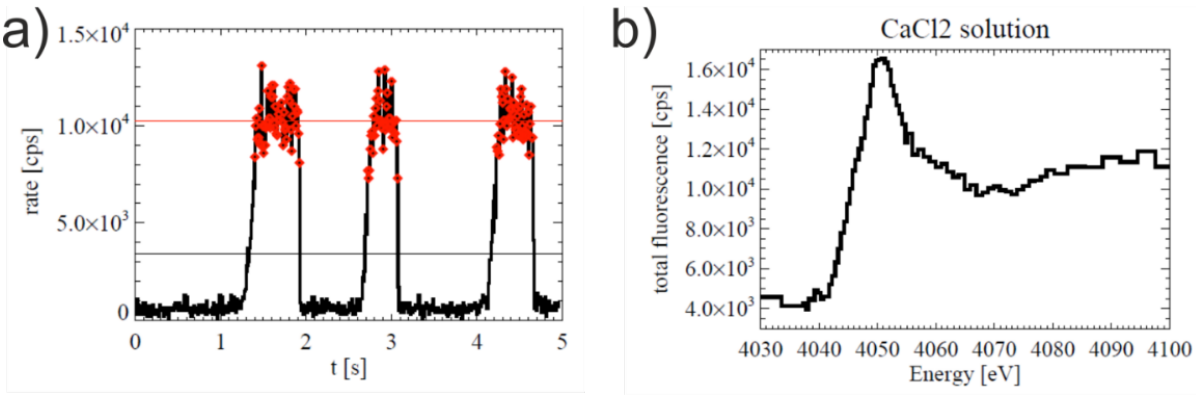



Figure 2: a) Fluorescence signal in individual droplets as a function of time (time interval = 10 ms). b) XANES for the Ca K-edge of 1 molar $CaCl_2$ solution in flowing droplet train.

Through the testing and development of these devices at the Pheonix Beamline at the Paul Scherrer Institute in Switzerland we were able to develop microfluidic connections compatible with environmental chambers at low pressures, as well as identify critical requirements for the use of microfluidic devices with synchrotron light sources in general, such as limiting radiation damage.

To address this issue of radiation damage we took two approaches, first through reductions in beam flux and the rastering of the beam the dosage each portion of the device received was limited, while effective this leads to a reduction in the resolution of data gathered. The second approach was to develop a device with a radiation tolerant backing, such as glass or silicon. These new devices allowed for much higher resolution spectra with measurements performed continuously for periods of up to 12 hours (a full shift), an example of these spectra can be seen in figure 3.

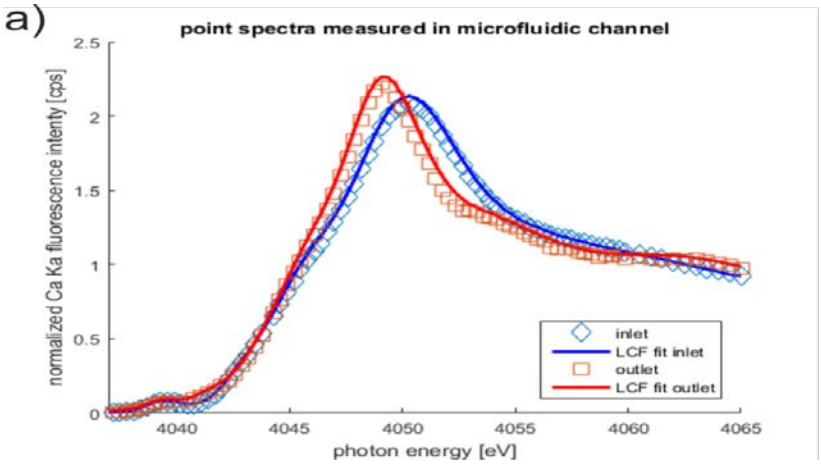



Figure 3. Fluorescence spectra of Ca ions measured and the inlet and outlet of a diffusion-reaction microfluidic cell indicating the shift in peak associated with the changing local environment around each Ca ion.

These findings and more specific details of microfluidic device fabrication and operation for use at synchrotron beamlines is currently being prepared for submission as a series of journal articles aimed at the journals Small and Lab on a Chip.

# OVERSEAS TRAVEL FELLOWSHIPS

## MR XIAORUI ZHENG FROM SWINBURNE UNIVERSITY VISIT TO THE UNIVERSITY OF CALIFORNIA (SAN DIEGO).

### Outcomes of ANN overseas travel fellowship

Xiaorui Zheng

Centre for Micro-Photonics in Faculty of Science, Engineering and Technology at Swinburne University of Technology, PO Box 218, Hawthorn, Victoria 3122, Australia

Introduction

Dr. Xiaorui Zheng's visit to Professor Ertugrul Cubukcu's research group in the Department of Nanoengineering at the University of California, San Diego, CA, United States has been supported by the Australian Nanotechnology Network (ANN) overseas travel fellowship. During Xiaorui's visit from from 1st Nov. 2016 to 1st Feb. 2017, fruitful research outcomes have been achieved including both the experimental and theoretical results. This report consists five parts, including Introduction, Experiment, Theory, Conclusion and Publications. The first realization of the graphene oxide (GO) polarizers will be discussed in the Experimental results. Also the theoretical calculations on transverse electric (TE) surface waves in two-dimensional (2D) heterostructures have been performed. Then the conclusions of the main research findings will be summarised. Finally, the publications result from the ANN overseas travel fellowship will be attached.

Experiment

The mid-infrared (MIR) radiation, in particular with the wavelength range from 3 μm to 30 μm, plays an indispensable role in a wide range of optical phenomena and applications, including the infrared (IR) imaging and sensing, aerospace engineering, medical science, military defense, and information and communications. However, the appropriate materials, especially the ones suitable for the deep MIR regime (>8 μm), are greatly restricted to Germanium-, Selenide-, and Fluoride-based materials such as Ge, ZnSe and BaF2, which are extremely fragile, hazardous, and costly. Therefore, it remains challenging yet crucial to acquire the ideal materials for the highly demanding MIR applications, which possess broadband MIR transparency, low losses, high refractive index, mechanical and chemical stability, cost-effective and rapid manufacturing capabilities.

The discovery of graphene plasmons has attracted enormous attention due to the potential to reshape the landscape of photonics and optoelectronics in the MIR and terahertz (THz) regimes. However, the considerable plasmon damping, the cost-ineffective mass production, the poor processability and nanostructuring capability of graphene have placed stringent restrictions for its practical MIR applications. In contrast, the chemically derived GO has been seen as an appealing alternative material due to its unique physical and chemical properties arising from the hybridization of the sp2 and sp3 carbon atoms. Most importantly, the optical and electrical properties of GO can be precisely tailored by manipulating the sp2-hybridized domains of GO during its reduction process, enabling numerous photonic and optoelectronic applications. However, the current optical characterizations of GO have been limited in the visible or near-infrared (NIR) regimes by using the conventional approaches such as ellipsometry, picometry or microscope. The optical properties of GO in the MIR regime are barely studied previously

owing to the constricted selections of both the available MIR characterization approaches and the unrevealed material band models, which significantly hampers its MIR photonic applications.

Compared with the largely developed MIR sources and detectors, the high performance MIR linear polarizer still remains in the primitive stages of development, which is though highly desired in various photonic and optoelectronic applications such as spectrometry, infrared ellipsometry, infrared sensors and optical communications. Although several MIR polarizers have been developed experimentally including the wire-grid polarizers, the dielectric multilayer polarizers and the grating polarizers, it is still challenging to realize an efficient MIR polarizer that has the high performance, the mechanical robustness, the non-toxic constitute materials, the cost-effective manufacturing and the broadband operational wavelengths over the entire MIR range, especially beyond the Silicon transparency window (>8 μm).

We have successfully adapted a model-free Kramers-Kronig (KK) method to characterize the fundamental optical properties of GO over the difficult-to-access wavelength ranges. As a result, the broadband dispersion relations of the GO thin film from the visible (200 nm) to the MIR (25 μm) ranges have been acquired for the first time by simply measuring its transmission spectrum. Most importantly, the successful demonstration of the model-free transmittance-based KK method provides a universal approach to acquire the fundamental optical parameters of the novel low-dimensional materials with the atomic-layer thickness especially in the less developed MIR or THz regimes. In addition, based on the acquired dispersion relations, the MIR GO polarizers with the high efficiency (~90%), the large extinction ratio (~20 dB) and the controllable working wavelength from 2 μm to 25 μm have been designed and realized both theoretically and experimentally. Excellent agreement among the theory, the simulation and the experimental measurement has been achieved, which further validates not only the design of the GO polarizer but also the measured dispersion relations of the GO thin film in the MIR regime. The mechanical robustness, the low-cost mass production and manufacturing, and the flexible integration capability of our GO polarizers offer great potential for various photonic applications particularly in the MIR regime.

The manuscript entitled “Graphene oxide mid-infrared optics for high performance linear polarizers” has been drafted and attached.

*Theory*

Layered materials have attracted considerable interest for advanced technological applications owing to the novel properties different from their bulk counterparts. Recently, 2D materials, seen as the physical limit, have been extensively studied because of their exceptional electronic, optoelctronic, electrochemical, mechanical and biomedical applications. Of particular interests are the enhanced light- matter interactions observed in various 2D layered materials through the dipole-type polaritonic excitations. For instance, graphene has been demonstrated to support electrically tunable and highly confined surface plasmon polaritons, promising for photonic and optoelectronic applications. The surface phonon polaritons have been successfully launched and detected in hexagonal boron nitride (h- BN) at the infrared regime, allowing for ray-like propagation exhibiting high quality (Q) factors and hyperlensing effects. The exciton polaritons have emerged as another exciting topic of interest in the monolayer transition metal dichalcogenides (TMDCs) owing to their optically prominent excitons with large binding energies.

Unlike the transverse magnetic (TM) surface plasmon polaritons, the unique transverse electric (TE) surface waves, firstly predicted in monolayer graphene, have been actively explored due to not only their fundamental interests, but their potential nanophotonic applications. Various 2D materials are predicted theoretically to support TE surface waves including the monolayer graphene, bilayer graphene, TMDCs monolayers , h-BN and monolayer silicene , . However, the experimental excitation and further detection of TE surface waves remain challenging largely owing to the extremely sensitive to the excitation environment and phase matching conditions. Moreover, the tiny effective model index close to air and the weak spatial confinement of the TE surface waves have greatly restricted their potential applications compared to that of the TM surface plasmon polaritons.

We propose a multi-layer 2D heterostructure of vertically stacked h-BN and tungsten disulfide ($WS_2$) monolayers, in which the prominent TE surface wave has been studied by rigorous transfer matrix methods. The dispersion curve of the TE surface wave shows a significant deviation from the light line near the A-peak absorptions of $WS_2$, corresponding a pronounced model index increase. By optimizing the layer numbers, the spatial confinement of the TE surface waves as small as 166 nm at the A-peak absorption wavelength has been achieved, corresponding to an over 80% confinement enhancement compared to that of the monolayer counterparts. Furthermore, the excitation of the TE surface waves via phase matching conditions has been proposed through a unique multi-layer 2D heterostructure with periodic circular hole arrays, which greatly alleviates its stringent excitation requirements. Moreover, the exciton-polaritons in such 2D heterostructure have been investigated owing to the strong coupling between the photons and excitons, corresponding to a Rabi splitting as large as 82 meV. Finally, an ultrasensitive gas sensor can be achieved by monitoring the photonic resonances as a function of the environment index, exhibiting a bulk refractive index sensitivity up to 602 nm/RIU (refractive index unit). Therefore, the proposed ultra-thin multi-layer 2D heterostructures with the prominent TE surface waves may provide a versatile and potentially attractive platform for future photonic and optoelectronic devices. Moreover, the rigorous analytical solutions can be widely used in predicting the extraordinary properties of the novel 2D heterostructures.

The manuscript entitled “Transverse electric surface waves in two-dimensional heterostructures” has been drafted and attached.

*Conclusion*

During the visit, for the first time, we have investigated the dispersion relations of the GO thin films by adapting the model-free transmittance-based KK relations, providing the significant optical parameters of GO for various photonic and optoelectronic applications in the MIR regime from 2 μm to 25 μm. As an example, we realized the freestanding MIR GO polarizers with controllable working wavelengths from 2 μm to 14 μm, large extinction ratio of 20 dB, flexible integration capability, chemical stability, and low-cost and fast manufacturing for the next-generation photonic applications in the MIR regime. Two coupling mechanisms of the GO polarizers have been analyzed and excellent agreement has been reached between the theoretical and experimental results. The successful adapting of the model-free transmittance-based KK relations in characterizing the ultrathin GO films opens up a novel avenue for the optical characterization of the novel low-dimensional materials with atomic-scale thicknesses, which is still challenging for the traditional spectroscope ellipsometry method. Moreover, the

attainableequency range can be greatly extended by combining various spectroscopic methods from the UV to microwave ranges, offering the optical properties over nearly the full spectrum and greatly promoting the design and fabrication of functional integrated photonic devices in the less developed MIR and THz range.

Moreover, the TE surface waves of the multi-layer 2D heterostructure have been studied numerically. The dispersion relations of the TE surface waves have been calculated through the rigorous transfer matrix method, which can be readily adopted to various 2D heterostructures. As an example, the multi- layer 2D heterostructures of vertically stacked h-BN and $WS_2$ are studied. Prominent TE surface waves of the heterostructure have been observed with greatly enhanced spatial confinement and considerable propagation lengths. In addition, a unique multi-layer 2D heterostructure with periodic hole arrays has been proposed and demonstrates the strong photon-exciton coupling as well as the ultrahigh sensitivity for the gas sensing. Therefore, the proposed ultra-thin multi-layer 2D heterostructures with the prominent TE surface waves may provide a versatile and potentially attractive platform for future photonic and optoelectronic devices. Moreover, the analytical solutions can be widely used in predicting the extraordinary properties of the novel 2D heterostructures

# OVERSEAS TRAVEL FELLOWSHIPS

## MR FRAN KURNIA FROM THE UNIVERSITY OF NEW SOUTH WALES VISIT TO THE CENTRE FOR NANOPHASE MATERIALS SCIENCES AT OAK RIDGE NATIONAL LABORATORY, USA

**Mr. Fran Kurnia from the University of New South Wales to visit Oak Ridge National Laboratory, USA,for a period of one month**

**Travel dates: 10th of April, 2016 to 7th of May, 2016.**

**Host supervisors: Dr. Rama Vasudevan, Dr. Sang Mo Yang, Dr. Sergei V. Kalinin**

The main focus of this trip was to use first-order reversal curve current-voltage (FORC-IV) spectroscopy, which is a unique facility available at the Center for Nanophase Materials Sciences, Oak Ridge National Laboratory (USA). During my visit, this facility was used to resolve the electrical properties of gallium phosphide (GaP) thin films for resistive switching applications. In resistive switching materials, there are several switching mechanisms that can occur such as Schottky barrier modulation, crystal phase transition and electrochemical metallization. In order to develop a robust electronic device based on memory switching, it is very important to understand the nanoscale mechanism that drives the switching process. Our measurements at CNMS have helped us to distinguish these mechanisms for our GaP thin films. The results from this work have been published in the *Journal of Materials Chemistry C* (DOI: 10.1039/C6TC04895A).

**Motivation and background:**

Resistive switching (RS) memory is one of the leading candidates for the next-generation of nonvolatile memory. Over the past decade, a large variety of materials have been found to exhibit RS behaviour, including binary/complex oxides, chalcogenides, and nitrides, as well as polymer materials. Interestingly phosphides, which form an important class of materials in the electronics industry, have not been studied in terms of RS behavior. Among the phosphide semiconductors, gallium phosphide (GaP) has a close lattice mismatch with silicon (Si) of 0.4% at room temperature and thus would offer the advantages of heteroepitaxial growth on and easy integration with Si. Due to these advantages, the development of high density nonvolatile memory directly on Si substrates using GaP would be significant.

Owing in part to the wide diversity of RS materials, the mechanisms controlling RS behaviour, which range from a filamentary-based switching mechanism to electronic band structure modulation (e.g. Schottky barrier change), are complex and not always well understood. However, irrespective of the macroscale mechanism, the underpinning processes, particularly the physico-chemical mechanisms of charge transport, occur at the nanoscale. Therefore, the use of advanced measurement techniques to resolve the spatial distribution of surface conductivity, such as FORC-IV spectroscopy, has become a valuable means of investigating RS at the nanoscale.

## Facilities:

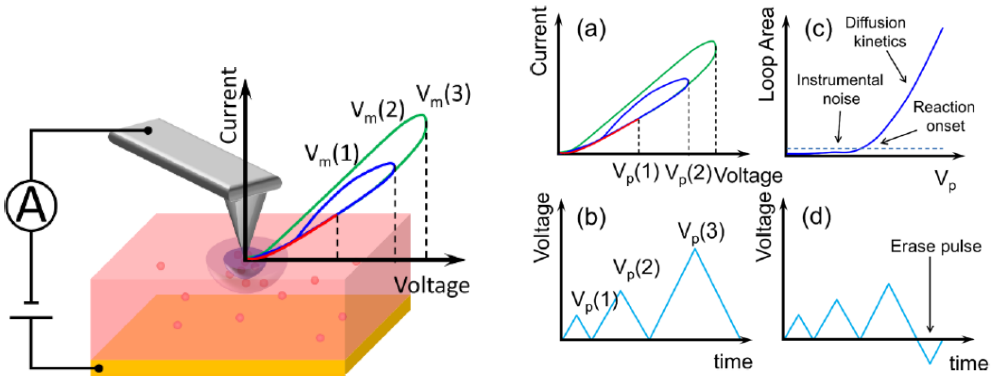



**Figure 1.** (Left) A schematic illustration of FORC-IV spectroscopy measurement $V_m$ is the maximum voltage that can be achieved for each loop; (Right) Principles of the FORC-IV measurement for mapping the conductivity of a material. (a) I-V curves, (b) Applied bias waveform, (c) Loop area as a function of peak bias ($V_p$), (d) Applied bias waveform with the activated "erase" pulse at the end. Images are taken from Strelcov et al.[1]

Our FORC-IV measurements were carried out by applying biases to Pt/Cr coated tips. The spatial resolution of the I-V maps is 25 nm.

## Results:

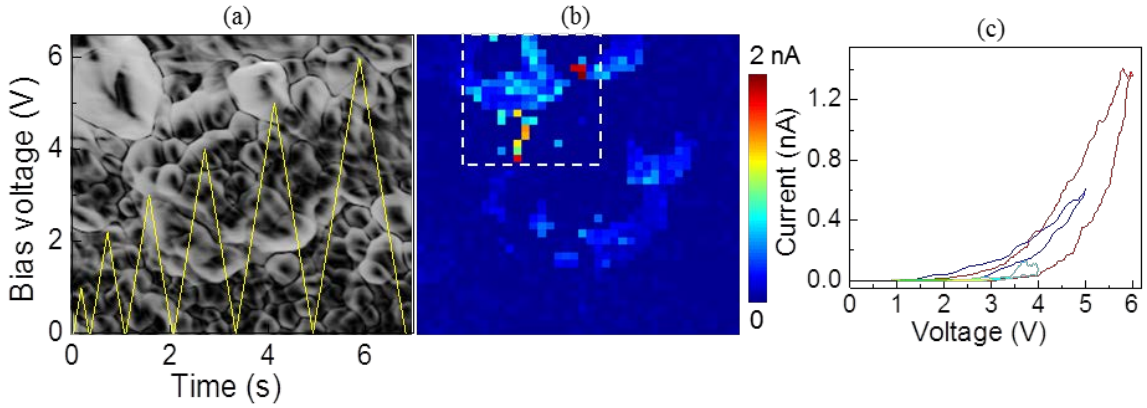



**Figure 2.** (a) Local slope image of the GaP thin film and FORC voltage waveform applied to this region. (b) Current map measured over 40 × 40 pixel grid covering 1 × 1 μm$^2$ of the GaP film surface at 6 V bias. (c) I-V curves averaged over 10% of the area shown in (b), i.e. the 16 × 16 pixel grid indicated by the white dashed-box in (b), covering the most conducting area. Images are taken from Kurnia *et al*.[2]

The surface conductivity of a GaP thin film was measured over a dense grid of 40 × 40 pixels covering a region of 1 × 1 μm$^2$ (Fig. 2a) by applying six triangular voltage waveforms with gradually increasing peak biases from 1 V to 6 V

for each point. It can be seen that the conductive points are concentrated in particular area (Fig. 2b), which corresponds to a GB region. Fig. 2c shows the large hysteresis windows in the I–V curves, obtained from the averaged I-V curves using data only for the points in the GB region. The averaged I-V curves using all the points in the mapped area show lower conductivity as well as smaller hysteresis windows. Based on these results, we were able to understand the mechanism of RS in GaP, which has not been observed before, and this can potentially establish GaP as a new RS material.

## Personal Note:

In addition to these experimental results, the visit to CNMS has also had significant benefits to my career development because I have built up my international network through working with world-leading experts at Oak Ridge National Laboratory. This will be beneficial not only at the present time but also throughout my future research career.

I would like to thank the Australian Nanotechnology Network (ANN) for the travel funding that supported my visit to CNMS.

**References:**

1. E. Strelcov, Y. Kim, S. Jesse, Y. Cao, I. N. Ivanov, I. I. Kravchenko, C.-H. Wang, Y.-C. Teng, L.-Q. Chen, Y. H. Chu, S. V. Kalinin. *Nano Lett.* **13**, 3455 (2013).

2. F. Kurnia, C. Liu, G. Liu, R. K. Vasudevan, S. M. Yang, S. V. Kalinin, N. Valanoor, J. N. Hart. *J. Mater. Chem. C* **5**, 2153 (2017).

MS EMMA BRISSON FROM THE UNIVERSITY OF MELBOURNE VISIT TO THE UNIVERSITY OF WARWICK.

# A Report about my Overseas Research Visit to the University of Warwick August-November2016

By Emma Brisson

*Emma is a third year PhD student under the joint supervision of Dr Luke Connal and Prof George Franks in the Department of Chemical and Biomolecular Engineering at the University of Melbourne. With the support of an Australian Nanotechnology Network Overseas Travel Fellowship, she undertook a three month research visit in the group of Prof Rachel O'Reilly in the Department of Chemistry at the University of Warwick from August-November 2016 to synthesize and self-assemble polymers that mimic proteins and peptides with amino acid functionality on their side chains.*

## Overview

The purpose of this visit was to work with the group of Professor Rachel O'Reilly to combine their expertise in block copolymer self-assembly with our expertise in the synthesis of highly functional, amino acid polymers. The Department of Chemistry at the University of Warwick is home to world leading polymer scientists, including Professor Rachel O'Reilly and her group. The opportunity to work in their world class laboratories and use their characterization facilities, as well as to work within her group was invaluable to this project and to my development as a polymer chemist and researcher.

## Aim

The aim of this collaboration is to make amino acid functional block copolymers and to self-assemble them into nanostructures; the unique chemistry of the amino acid side chains can be used to reversibly lock the polymer nanostructures. This project combines the synthetic strategies developed in the Connal group in Melbourne with the O'Reilly group's expertise in block copolymer self-assembly and characterization.

## Background

Nature has evolved proteins, highly specific and precise molecular machines, which perform catalytic and mechanistic functions in order to sustain life. The three dimensional shape of proteins in combination with their chemistry dictates the function they perform as well the specificity of their interactions with other biomacromolecules. There are 21 unique amino acids, which form polypeptides when they condense into a polyamide macromolecule, shown in Figure 1. The ordered sequence of amino acids in the polypeptide results in specific folding and shapes. The proximity of the R groups and their interactions in folded proteins can facilitate catalysis and form specific metal ion binding sites that can activate function.

The vital role that amino acid R-groups play in the structure and function of proteins makes them attractive functional moieties to attach to synthetic polymers. Imitating bio macromolecular structures with synthetic amino acid functional polymers has led to the development of antifouling materials, nanoparticle drug delivery, catalytic polymers and nanoparticles, conducting materials, and more.


*Figure 1. All amino acids (a) have 3 functional groups: an amine, a carboxylic acid, and a side chain functionality that makes each amino acid unique. This R group can have acidic (negative charge), basic (positive charge), polar (uncharged), and neutral/hydrophobic (uncharged) functionality. When multiple amino acids condense, they form a polypeptide (b) which has a polyamide backbone with the R-groups pendant as side chains.*

The vital role that amino acid R-groups play in the structure and function of proteins makes them attractive functional moieties to attach to synthetic polymers. Amino acid functional polymers are synthetic polymers with amino acids as pendant moieties on the side chains of the polymer, illustrated in Figure 2.


***Figure 2.*** *A schematic representation of a synthetic polymer with amino acids as pendant moieties.*

Due to the highly functional nature of amino acids, the synthesis of amino acid functional materials is tedious and usually requires protection group chemistry. In the Connal group, Emma has developed a versatile, protecting group free synthesis of amino acid functional polymers using carbonyl condensation chemistry, illustrated in Figure 3. Using an aldehyde functional polymer as a functional platform, the condensation of the aldehyde with the free amine of amino acids forms an imine. The imine can be preserved for dynamic conjugation of the amino acid to the polymer, or it can be readily reduced to an amine for permanent attachment of the amino acid. Using this approach, amino acid functional materials can be synthesised in two steps.

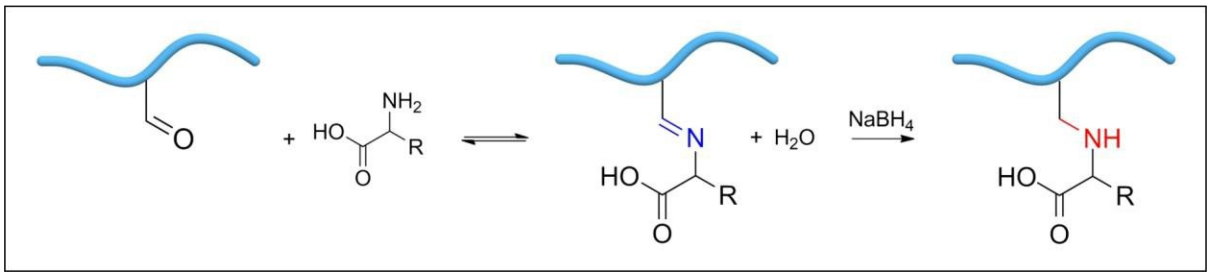



***Figure 3.*** *Carbonyl condensation, specifically reductive amination, as a means to functionalize aldehyde functional polymers with amino acids. This approach does not require any protecting groups, is very benign chemistry, and allows for the retention of the amino acid R group.*

Our simplified synthesis of amino acid functional materials makes it easy to synthesize a wide range of amino acid functional materials, which allows us to easily explore the side chain chemistry as a means to reversibly lock polymer nanostructures. The inherent biocompatibility of the amino acids allows for biological applications, and the reversible locking using the chemistry of amino acids allows us to mimic specific aspects of biological macromolecules.

## How This Project Fits In

The application of this synthesis to block copolymers allows for the use of the interesting chemistry of the amino acid R-groups to create biomimetic, reversible, self-assembled polymer nanostructures. The O'Reilly group's expertise in polymer self-assembly and in polymer nanostructure characterization is an ideal overlap with the study of these amino acid functional block copolymer assemblies.

The purpose of the visit was to explore the self-assembly of amino acid block copolymers. The synthesis strategy was to functionalize aldehyde functional polymers; the copolymer system we used was poly(N-isopropylacrylamide)-b-poly(4-formylphenylacrylate). When synthesizing base block copolymers, getting good control over the dispersity of the resulting polymers was problematic. As a result, upon arrival in the UK, it was decided that we would try a few different synthetic strategies, as well as work on the characterization of polymer nanostructures.

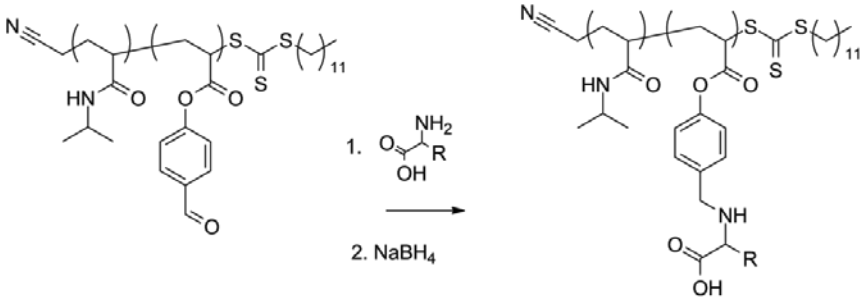
## What I Accomplished

At the University of Warwick, I worked on three different things: 1. Polymer synthesis; 2. Polymer self-assembly; and 3. Polymerization Induced Self-Assembly. Three approaches were taken to synthesize amino acid functional block polymers that allowed for good control over the size of the resulting polymers.

### 1. POLYMER SYNTHESIS

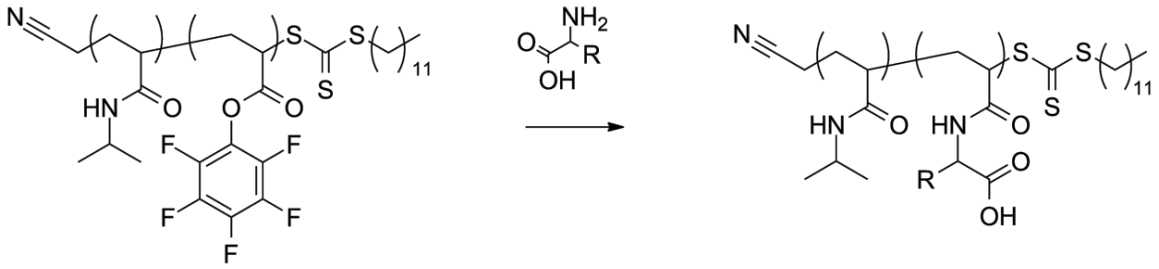
Three approaches were taken to synthesize amino acid functional block polymers that allowed for good control over the size of the resulting polymers.

The first was the functionalization of the polymers I brought with me to Warwick (Scheme 1), poly(n-isopropylacrylamide)-block-poly(formyphenylacrylate) (PNIPAM-b-PFPA). These polymers had high polydispersities (1.5-1.8) which indicates that the polymerization could be better controlled. However, these materials were functionalized with glycine and histidine. Upon analysis of these histidine and glycine functional block copolymers, it was found that the ester was hydrolyzed, and we made a decision to synthesize polymers without an ester group.




***Scheme 1.*** *The addition of amino acids to poly (n-isopropylacrylamide)-block-poly (formyphenylacrylate) (PNIPAM-b-PFPA) was not found to cleave during the formation of the block copolymers.*

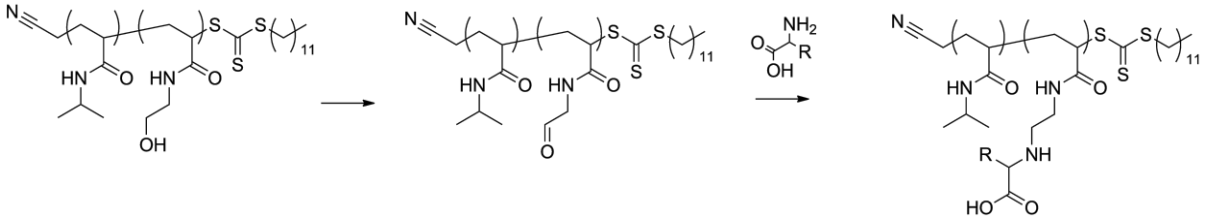
The second approach to polymer synthesis was to form block copolymers with activated ester containing monomers that could readily react with the amine of the amino acids. This approach was successful. To use this approach, I synthesized activated ester containing monomers and used those to form the block copolymers (pictured in Scheme 2 is poly (n-isopropyl acrylamide)-block- poly (pentafluorophenylacrylate) (PNIPAM-b-PFPA). The functionalization of the activated esters was done using moisture sensitive techniques that I learned and implemented at the University of Warwick. Ultimately, it was decided that we would not use this approach in the project for continuity with my previous work. However the experience making these materials and working with dry chemistry techniques was valuable.



***Scheme 2.*** *Polymers with activated esters were synthesized to facilitate the functionalization of the polymers with amino acids.*

The third synthetic approach to the synthesis of amino acid functional block copolymers was to get good control over to polymerization with an acrylamide monomer, N-hydroxyethyl acrylamide (HEAm). This monomer polymerizes nicely and block copolymers with low polydispersities (below 1.2) were obtained. The alcohols were oxidized using Swern oxidation to form aliphatic aldehydes, and these were reacted with amino acids to form amino acid functional block copolymers, illustrated in Scheme 3. The aliphatic aldehydes are much more reactive than benzaldehydes, and crosslinking was a problem. Additionally, the reactivity of the aliphatic aldehyde was different than that of the benzaldehydes, so only 30% conversion of the aldehydes to amino acids was achieved. However, this approached enabled the synthesis of amino acid functional block copolymers with low polydispersities.

Back in Melbourne, this approach can be fine-tuned to achieve better amino acid conversion, by using acid catalysis or by treating with different bases.



***Scheme 3.*** *The Swern oxidation of an alcohol containing polymer to generate an aliphatic aldehyde and its subsequent reductive amination with amino acids was the third approach*

## 1. POLYMER SELF-ASSEMBLY

As the synthesis of the amino acid functional polymers was being tackled with different approaches, the self-assembly of the base polymer, poly (n-isopropylacrylamide)-block-poly (formyphenylacrylate) (PNIPAM-b-PFPA), was investigated. Micelles were formed using the solvent switch method (shown in Figure 4) and were investigated using dynamic light scattering. The aldehydes presented inside the micelles, and crosslinking using a diamine, cysteine methylester, was attempted. The crosslinked micelles were analysed using Gel Permeation Chromatography with a triple detection system, which tells information about the degree of crosslinking. A small high molecular weight peak indicates the success of the locking of the micelles, but also indicates that the crosslinking conditions can be improved to have a larger number of locked micelles.

The ability to self-assemble and lock these micelles at the University of Warwick was an excellent experience. The use of triple detection in gel permeation chromatography for this purpose, as well as the group expertise in micelle formation and analysis using DLS is knowledge I will bring back to the University of Melbourne and use to study the self-assembly of the amino acid functional block copolymers.

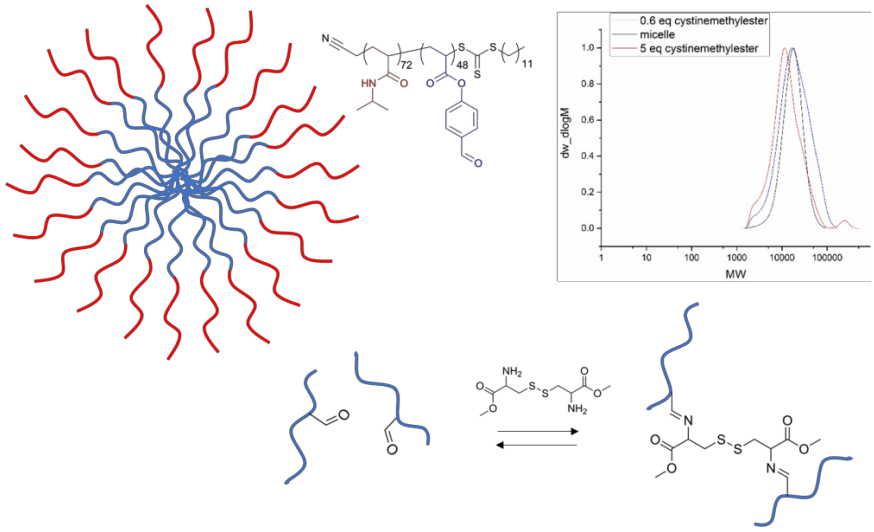



***Figure 4.*** *Micelles were formed from PNIPAM-b-PFPA using the solvent switch method. These micelles were analysed by DLS. The addition of a diamine crosslinker, cysteine methyl ester, resulted in a small number of locked micelles, indicated by a small high molecular weight peak in the GPC spectrum.*

## 2. POLYMERIZATION INDUCED SELF-ASSEMBLY (PISA)

When analysing poly(n-isopropylacrylamide)-block-poly(N-hydroxyethyl acrylamide) (PNIPAM-b- PHEAm), it was observed that self-assembly was occurring in chloroform. As a test, this chain extension was tried in chloroform and mono-disperse polymer self-assemblies were observed. As a result, some data for the formation of a phase diagram was acquired. PISA is rarely reported in chloroform. Working on this was a great opportunity to learn about self-assembled nanostructures and their characterization. The structures formed were micelles

and vesicles and these were characterized by transmission electron microscopy (TEM). I learned to make these samples on numerous substrates and we managed to find good conditions to see some of these particles.

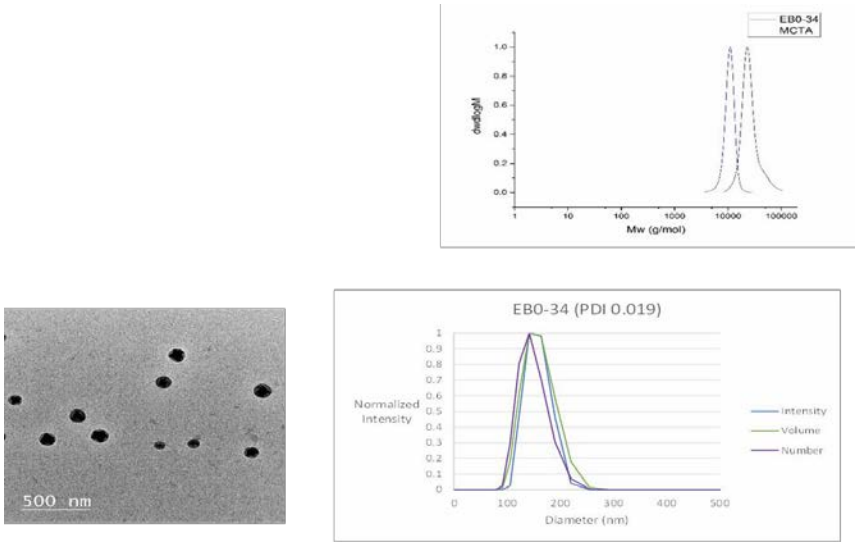



***Figure 5.*** *TEM, GPC and DLS showing the self-assembled structures formed, as well as their mono- dispersity and good control over molecular weight.*

## Professional and Skills Development

The Department of Chemistry at the University of Warwick is a world leading facility in the field of polymer science. From the synthesis of novel polymers to their assembly and application in cutting edge technologies, the University of Warwick has experts in all aspects. Working closely with pharmaceutical sciences, the polymer science groups there are expertly solving world class problems. A hub for collaborations, it was an excellent opportunity to be immersed in such a dynamic and exciting research environment. The laboratories and characterization facilities available were extraordinary and my knowledge of polymer characterization has grown immensely from this experience.

In the O'Reilly group, I was able to learn a great number of skills in polymer synthesis and in the characterization of polymer self-assemblies. My synthetic skills in the synthesis of block copolymers was greatly improved during my visit in the group. The use of activated esters in polymer synthesis is a very useful skill in the synthesis of highly functional materials, and I was able to gain some experience using it on this visit. I also learned different methods of self-assembling polymers. The use of temperature and solvent switch to make monodisperse micelles and the characterization of those assemblies in solution with DLS and SLS as well as their characterization with electron microscopy was also invaluable in this exchange.

Having the expertise of the O'Reilly group members while learning to use these methods for the characterization of polymer self-assemblies was a great opportunity. In three months, I learned more than I could have learned in one year on my own. Working within a well-established research group was invaluable from this perspective.

# OVERSEAS TRAVEL FELLOWSHIPS

## MS WEIJIE LI FROM THE UNIVERSITY OF WOLLONGONG VISIT TO DONGGUK UNIVERSITY IN SEOUL, KOREA.

Weijie Li will be taking up the fellowship in 2017

## MISS YANYAN JIANG FROM THE UNIVERSITY OF NEW SOUTH WALES VISIT TO THE UNIVERSITY OF COLORADO, BOULDER, USA

Yanyan will be taking up the fellowship in 2017

## MS MUN TENG SOO FROM THE UNIVERSITY OF QUEENSLAND VISIT TO THE INSTITUTE MICROSTRUCTURE AND PROPERTIES OF ADVANCED MATERIALS, BEIJING UNIVERSITY OF TECHNOLOGY (BJUT), CHINA.

Mun will be taking up the fellowship in 2017

## DR. MARKUS MUELLNER, SCHOOL OF CHEMISTRY, UNIVERSITY OF SYDNEY VISIT TO AALTO UNIVERSITY, FINLAND.

Markus will be taking up the fellowship in 2017

## DR TANVEER HUSSAIN FROM THE UNIVERSITY OF QUEENSLAND VISIT TO THE UNIVERSITY OF TEXAS, USA.

Tanveer will be taking up the fellowship in 2017

## DR ROEY ELNATHAN FROM THE UNIVERSITY OF SOUTH AUSTRALIA VISIT TO THE MAX PLANCK INSTITUTE FOR MEDICAL RESEARCH, STUTTGART, GERMANY.

Roey will be taking up the fellowship in 2017

## MS LARISSA HUSTON FROM THE AUSTRALIAN NATIONAL UNIVERSITY VISIT TO THE OAK RIDGE NATIONAL LABORATORIES, TENNESSEE, USA.

Larissa will be taking up the fellowship in 2017

# Workshops, Conferences and Events

## 7TH INTERNATIONAL NANOMEDICINE CONFERENCE, 27/06/2016 - 29/06/2016 - COOGEE BEACH, SYDNEY

### 7th International Nanomedicine Conference Report

### prepared for the Australian Nanotechnology Network

The organising committee of the 7th International Nanomedicine Conference, and our co-hosts the Australian Centre for NanoMedicine (ACN) and the ARC Centre of Excellence for Convergent Bio-Nano Science and Technology (CBNS) would like to thank the Australian Nanotechnology Network (ANN) for their sponsorship and for providing funds to assist students and ECRs in attending the conference.

The conference attracted more than 210 delegates from around Australia and internationally to discuss key themes in the field of nanomedicine: Drug Delivery; Sensors and Imaging; Bio-Nano Interactions; Bio- active Materials; Vaccines; Social Aspects; and Clinical Challenges. Over the course of three days, 5 plenary, 12 Keynote, 17 invited, and nearly 60 oral presentations (from submitted abstracts) were given along with 48 posters. Through the funding provided by the ANN, the conference was able to provide support for 13 students and ECRs from 7 different research institutions (see table next page).

Of the delegates supported by ANN funds, four won accolades for their presentations at the conference:

**Mr Joshua Glass** - awared Best Oral Presentation by a PhD Student for his oral presentation "*Harnessing human blood to ex- amine bio-nano interactions at the cellular level*" as well as a 2nd Place Poster Prize for his poster presentation on "*Harnessing bi-specific antibodies for cell-targeting of immunologically stealth poly(ethylene glycol) particles*"

**Ms Laura Selby** - Honourable Mention for Best Oral Presentation by a PhD Student

**Ms Danzi Song** - Honourable Mention for Best Oral Presentation by a PhD Student

**Dr Amirali Popat** - Honourable Mention for Best Oral Presentation by an Early Career Researcher

The ANN's sponsorship was acknowledged throughout the proceedings including verbally during the conference opening and closing ceremonies, and on slides in all conference rooms between sessions. In addition, the ANN logo was linked to the ANN website on the conference website, and background and contact information for the ANN was printed in the conference program booklet

# WORKSHOPS, CONFERENCES AND EVENTS


Joshua Glass receives his prize for 2nd Place Poster Presentation from Prof Vincent Romello (Editor-in-Chief of Bioconjugate Chemistry

ANN sponorship provided $350 in funding for each of the following PhD students and ECRs.

| Bursary Recipient | Abstract Title |
|---|---|
| Ms Stacey Bartlett<br>The University of Queensland | Development of peptide-based oral vaccines against hookworm |
| Ms Lisa Belfiore<br>University of Wollongong | Development of Novel Dual-Targeted Drug-Loaded Liposomes for the Treatment of uPAR/HER2-Positive Metastatic Breast Cancer |
| Mr Patrick Charchar<br>RMIT University | Computational modelling of peptide-gold nanoclusters for biomedical applications |
| Dr Maarten Danial<br>CSIRO | Combating HIV Before and After Host Cell Infection with Sulfonated Poly- mers |
| Mr Joshua Glass<br>The University of Melbourne | Harnessing human blood to examine bio-nano interactions at the cellular level |
| Dr Sarvesh Kumar Soni<br>RMIT University | Gas adsorption by plasmid DNA and DNA-[Bmim][$PF_6$] construct: A QCM based mechanistic study |
| Ms Francesca Maclean<br>Australian National University | In vitro and in vivo assessment of self-assembled peptide/polysaccharide hydrogels for brain repair after injury |

| | |
|---|---|
| Ms Reshma Nevagi<br>The University of Queensland | Chitosan-based vaccine constructs against Group A streptococci (GAS) infection |
| Dr Amirali Popat<br>The University of Queensland | Enhancing Delivery of Nutraceuticals using Mesoporous Silica Nanoparti- cles |
| Dr Rajesh Ramanathan<br>RMIT University | Rapid colorimetric apta-biosensing platform for selective detection of me- thicillin resistant Staphylococcus aureus |
| Dr Sampa<br>Sarkar RMIT | Model biomimetic lipid membranes based on quaternary lipid-water sys- tems for encapsulation of bioactive molecules |
| Ms Laura Selby<br>Monash University | Understanding Bio-Nano Interactions Using Molecular Sensors |
| Ms Danzi Song<br>The University of Melbourne | Surface Chemistry Dependent Biological Behaviour of Polymeric Particles |

On behalf of the Conference Organising Committee, thank you again for your support.

Professors Maria Kavallaris and Justin Gooding

Co-Chairs of the 7th International Nanomedicine Conference Co-Directors, Australian Centre for NanoMedicine

# WORKSHOPS, CONFERENCES AND EVENTS

## 5TH INTERNATIONAL SYMPOSIUM ON GRAPHENE DEVICES, 11TH-14TH JULY, GRIFFITH UNIVERSITY, QUEENSLAND COLLEGE OF ARTS, BRISBANE

The 5th International Symposium on Graphene Devices (ISGD-5), is the principal meeting addressing advanced graphene applications, offering a unique forum to review the present status, the latest developments, future prospects and related fundamental studies, covering both state-of-the-art experimental and theoretical discoveries. This continues a biennial series of symposiums initiated in Japan, at the University of Aizu in 2008, at the Tohoku University, Sendai in 2010, at the Synchrotron SOLEIL in Saint Aubin, France, in 2012, and most recently, in Seattle in 2014. The A&S Committees of ISGD in 2014 had endorsed the bid to host ISGD-5 in Brisbane, with A/Prof.Francesca Iacopi and Prof.Michael Fuhrer as Chair and Co-Chair, respectively.


The conference, also announced on the Sydney Morning Herald (http://www.smh.com.au/technology/technology-news/graphene-200-times-stronger-and-six-times-lighter-than-steel-20160710-gq2d1b.html) and the Brisbane Times (http://www.brisbanetimes.com.au/technology/technology-news/graphene-200-times-stronger-and-six-times-lighter-than-steel-20160710-gq2d1b.html) , has been very successful, hosting 85 total participants with 71 scientific presentations (51 oral presentations and 20 posters). We had about 30% overseas presence, from Singapore, Japan, Korea, China, France, Germany, Sweden, Russia, Poland and the USA. 32 were PhD students or Early Career Researchers from Australian and overseas universities. Here below the list of the 10 students and ECRs from Australian Universities who benefitted from the ANN Bursary scheme (waived registration fee):

| ANN Bursary | Presentation Title and Authors |
|---|---|
| **Mr. Rajni Garg** University of South Australia, Australia | Work Function Engineering of Graphene for the Organic device compatibility Rajni Garg, Mats R. Andersson |
| **Mr. Jingyang Peng** Swinburne University of Technology, | Surface-plasmon enhanced mid-infrared graphene photodetector Jingyang Peng, Benjamin P. Cumming and Min Gu |
| **Dr. Shayan Seyedin** Deakin University, Australia | Knittable Graphene Oxide Fibres Produced by Dry-jet Wet-spinning Shayan Seyedin, Andrew I. Minett and Joselito M. Razal |
| **Dr. Dong Han Seo** Manufacturing Business Unit - CSIRO, Australia | Ambient-Air, compressed gas free CVD Synthesis of Graphene from Renewable Biomass D. H. Seo, S.Pineda, Z. J. Han and K. Ostrikov |
| **Mr. Shaikh Nayeem Faisal** University of Sydney, Australia | Nanomaterials Embedded Nitrogen-doped Graphene for Advanced Energy Storage and Conversion Shaikh Nayeem Faisal and Andrew I. Minett |
| **Mr. Robi Datta** RMIT University, Australia | Surface Functionalised MoO3 Nanosheets for Heavy Metal Sensing Robi Datta, Paul Atkin, Benjamin J. Carey, Kourosh Kalantar-zadeh and Torben Daeneke |
| **Mr. Paul Atkin** RMIT University, Australia | Synthesis and application of carbon quantum dot-functionalised 2D tungsten disulfide Paul Atkin, Torben Daeneke, Yichao Wang and Kourosh Kalantar-zadeh |
| **Ms. Litty Thekkekara** Swinburne University of Technology, Australia | Effect of direct laser writing on the reduction of graphene oxides Litty V. Thekkekara and Min Gu |
| **Mr. Shafique Pineda** CSIRO Manufacturing, Australia | Multifunctional Graphene Micro-Islands: Single-Step, Low-Temperature Plasma-Enabled Synthesis and Facile Integration for Bioengineering and Genosensing Applications Shafique Pineda, Fabricio Frizera Borghi, Dong Han Seo, Samuel Yick, Timothy van der Laan, Zhao Jun Han and Kostya (Ken) Ostrikov |
| **Dr. Adrian Murdock** CSIRO Manufacturing, Australia | Vertical graphene nanosheet dispersions Adrian T. Murdock, Dong Han Seo, Zhao Jun Han, Kostya (Ken) Ostrikov |

The conference Chairs acknowledge financial support by the ANN, the Office for Naval Research Global, Springer, QUT (for lending “The Cube” as electronic poster venue), the Monash Centre for Atomically Thin Materials, and the Griffith Environmental Futures Research Institute. Springer has offered 3 x 100 EUR book vouchers for the best student poster prizes, which were awarded to Mr Robi Datta from RMIT, Mr Shafique Pineda from CSIRO and Ms Iolanda Di Bernardo from QUT.

The conference was officially opened by Prof.Ned Pankhurst, SDVC(R) Griffith University, and Dr. Geoff Garrett, the Queensland Chief Scientist, and followed by a “Welcome to Country” performance by the Yuggera group, Brisbane. We have welcomed Prof.Gordon Wallace from U Wollongong as Keynote Speaker and a total of 19 invited speakers plus 2 selected PhD students who were upgraded to an invited slot. High quality talks were presented showing the

breadth and state-of-the-art of graphene application research, from improved understanding of synthesis processes, to application from bio-technology and healthcare to electronics, energy, sensors and touch-screens and optoelectronics.

The conference ended with the announcement of the decision to hold ISGD-6 in St.Petersburg, Russia in 2018, organized by the Ioffe Institute, and a visit to the Lone Pine Koala Sanctuary.

Very positive comments were heard from the attendees, especially the PhD student delegates who deeply appreciated their opportunity to closely interact with world -leaders in graphene research.

| Speaker | Presentation Title |
|---|---|
| **Gordon Wallace**<br>**University of Wollongong,**<br>**Australia** | GRAPHENE. THE JOURNEY FROM THE NANODOMAIN TO MACROSCOPIC DEVICES (Keynote) |
| **Alexander Lebedev,**<br>**Ioffe Institute,**<br>**RUSSIA** | GRAPHENE ON SiC SUBSTRATES: GROWTH, INVESTIGATION AND SENSORS APPLICATION |
| **Alexander Tzalenchuk,**<br>**National Physics Laboratory,**<br>**UK** | INFLUENCE OF IMPURITY SPIN DYNAMICS ON QUANTUM TRANSPORT IN EPITAXIAL GRAPHENE |
| **Akira Toriumi,**<br>**University of Tokyo,**<br>**JAPAN** | RANDOM TELEGRAPHIC SIGNALS OBSERVED IN ATOMICALLY THIN MoS2 FETs |
| **Claire Berger,**<br>**Institut Neel, FRANCE** | STRUCTURED EPITAXIAL GRAPHENE AND BALLISTIC TRANSPORT |
| **Baohua Jia,**<br>**Swinburne University,** | GRAPHENE OXIDE OPTOELECTRONIC DEVICES BY 3D LASER PRINTING |
| **Qin Li**<br>**Griffith University,**<br>**AUSTRALIA** | ENGINEERING THE SURFACE STATES FOR TUNING THE BRIGHT CARBON NANODOTS |
| **Deji Akinwande,**<br>**UT Austin,**<br>**USA** | 2D ADVENTURES: FROM GRAPHENE TO PHOSPHORENE TO SILICENE, PROGRESS AND COMMERCIALIZATION |
| **Dawei Su for Guoxiu Wang,**<br>**University of Technology Sydney,**<br>**AUSTRALIA** | GRAPHENE-BASED FUNCTIONAL MATERIALS FOR ENERGY STORAGE DEVICES |
| **Joshua Caldwell,**<br>**Naval Research Laboratories,**<br>**USA** | Mid-IR TO THz POLARITONICS: REALIZING ALTERNATIVE IR MATERIALS |
| **Lim Chwee Teck,**<br>**National University of Singapore,** | 2D MATERIALS FOR BIOMEDICAL APPLICATIONS |

| | |
|---|---|
| **SINGAPORE** | |
| **Kostya Ostrikov,**<br>**CSIRO and Queensland University of Technology, AUSTRALIA** | NANO-SCALE, ATOMIC-THICKNESS PLASMA PROCESSING OF FUNCTIONAL 2D MATERIALS |
| **Kourosh Kalantar-Zadeh,**<br>**RMIT,**<br>**AUSTRALIA** | MODULATING TRIONS AND EXCITONS IN TWO-DIMENSIONAL MOS2 BY ACOUSTIC MEANS |
| **Kurt Gaskill,**<br>**Naval Research Laboratories,**<br>**USA** | RECENT PROGRESS ON EPITAXIAL GRAPHENE DETECTORS OPERATING FROM THE GHz TO THz RANGE |
| **Maki Suemitsu,**<br>**Tohoku University,**<br>**JAPAN** | RECENT PROGRESS IN THE EPITAXIAL GRAPHENE FORMATION ON 3C-SIC/SI SUBSTRATES |
| **Mark Edmonds,**<br>**Monash University,**<br>**AUSTRALIA** | ELECTRONIC PROPERTIES OF HIGH-QUALITY EPITAXIAL TOPOLOGICAL DIRAC SEMIMETAL THIN FILMS |
| **Sebastien Lebegue,**<br>**Universite de Lorraine, FRANCE** | NEW TWO DIMENSIONAL COMPOUNDS: BEYOND GRAPHENE |
| **Shaffique Adam,**<br>**National University of Singapore,**<br>**SINGAPORE** | THE ROLE OF ELECTRON-ELECTRON INTERACTIONS IN GRAPHENE |
| **Ulrich Starke,**<br>**Max-Planck Institut,**<br>**GERMANY** | EXTREME DOPING AND MANY-BODY INTERACTION IN EPITAXIAL GRAPHENE ON SiC(0001) |
| **Yuerui Lu,**<br>**Australian National University,**<br>**AUSTRALIA** | EXTRAORDINARY EXCITONS IN PHOSPHORENE |
| **Viet Phuong Pham,**<br>**Sungkyunkwan University,**<br>**Korea** | A CHLORINE-TRAPPING IN CVD BILAYER GRAPHENE FOR RESISTIVE PRESSURE SENSING WITH HIGH DETECTION LIMIT AND HIGH SENSITIVITY (upgraded) |
| **Trong Toan Tran,**<br>**University of Technology Sydney,**<br>**AUSTRALIA** | QUANTUM EMISSION FROM HEXAGONAL BORON NITRIDE MONOLAYERS (upgraded) |

# WORKSHOPS, CONFERENCES AND EVENTS




# WORKSHOPS, CONFERENCES AND EVENTS

## 8TH INTERNATIONAL SYMPOSIUM ON NANO AND SUPERMOLECULAR CHEMISTRY, 13/07/2016 - 16/07/2016 – BRISBANE

### Conference overview

The 8th International Symposium on Nano &Supramolecular Chemistry (8th ISNSC) was held at Mercure Hotel, Brisbane, Australia during 13-16, July 2016. The aim was to bring 150-200 delegates to the symposium from all over the world, working in nano- and supramolecular chemistry and the applications of functional materials in diverse areas.

Details of funding recipients

**List of students/ECRs receiving funding from ANN**

| Name | Position | Institution |
|---|---|---|
| Zeta Chen | ECR | Institute of Health and Biomedical Innovation & Science and Engineering Faculty Queensland University of Technology |
| Fei Wei | PhD | Institute of Health and Biomedical Innovation & Science and Engineering Faculty Queensland University of Technology |
| Yinghong Zhou | ECR | Institute of Health and Biomedical Innovation & Science and Engineering Faculty Queensland University of Technology |
| Ehsan Eftekhari | ECR | Environmental Engineering & Queensland Micro- and Nanotechnolog y Centre, |
| Nikhil Aravindaks han | PhD | Environmental Engineering & Queensland Micro- and Nanotechnolog y Centre, Griffith University |
| Xingxing Gu | PhD | Environmental Futures Research Institute, Griffith University |
| Xuecheng Yan | PhD | Queensland Micro- and Nanotechnolog y Centre, Griffith University |
| Yi Jia | ECR | Queensland Micro- and Nanotechnolog y Centre, Griffith University |
| Emily Rames | PhD | School of Science and Engineering, University of the Sunshine Coast |
| Bradley Harding | PhD | School of Science and Engineering, University of the Sunshine Coast |
| Shan Liu | PhD | Centre for Future Materials, University of Southern Queensland |
| Zuhua Zhang | ECR | Centre for Future Materials, University of Southern Queensland |

### Outcomes

The **8th ISNSC** featured outstanding plenary speakers with international reputations, as well as an oral / poster session dedicated for early-career researchers (ECR) and PhD students. Awards were given to ECR and students from Wiley (*Small*) and Springer (2 x 500 USD worth of Springer books). Selected full papers after review were published in a special issue of *Aus. Chem.*

# WORKSHOPS, CONFERENCES AND EVENTS

## 36TH AUSTRALASIAN POLYMER SYMPOSIUM (36APS) 20/11/2016 - 23/11/2016 - LORNE, VICTORIA

The 36th Australasian Polymer Symposium (APS) ran from the 20th to 23rd of November 2016, and was hosted in the idyllic seaside town of Lorne, Victoria. APS is a consistently well-attended conference and 2016 was no exception with 295 delegates making the trip to Lorne to hear from 200 presenters of all career levels, including 6 plenary and 28 keynote speakers from institutions both within Australia and internationally.

The conference benefited from a series of exceptional plenary speakers, beginning with Professor Tom Davis from Monash University, who presented the cutting edge work currently being undertaken at the interface of polymer science and bionanotechnology in the ARC Centre of Excellence (CoE) in Convergent Bio-Nano Science and Technology (CBNS), of which Professor Davis is both the director and a chief investigator. This set the theme for many of the presentations to come from staff and student researchers of the CoE in CBNS, who were well represented at APS.

Professor Greg Qiao, RACI Polymer Division Chair (right), awards the Batteard-Jordan Australian Polymer Medal

The opening session of the conference also saw the presentation of the prestigious Batteard-Jordan Australian Polymer Medal. The Batteard-Jordan medal is the highest award of the RACI Polymer Division and is given for outstanding achievement in polymer science in Australia, a criterion which Professor Davis has certainly met through his work with the CoE and previously.

Following Professor Davis was Professor Richard Spontak from North Carolina State University. In his to Professor Tom Davis, University of Melbourne (left thermoplastic elastomers, Richard seeks to 'teach old materials new tricks.' He achieves this through a combination of inventive processing and meticulous characterization to select conditions which can induce unexpected behaviours in previously well-studied work with shape memory materials and conductive materials, such as improved elasticity of thermoplastics.

Professor Heather Maynard from the University of California opened the second day of presentations with her plenary discussing the use of glycopolymers to stabilise a range of enzymes and proteins, improving their utility in a range of applications from food science to therapeutics. This was followed on the third day by Professor Frank Caruso from the University of Melbourne, who is also part of the CoE in CBNS. In his presentation Professor Caruso elaborated on work mentioned in passing by Professor Davis in the opening plenary. In particular he spoke of the challenges and recent advances in the field of bio-responsive polymeric materials and the ways in which their responsiveness can be capitalised upon for nanoparticle-based drug delivery. After Caruso's talk the Polymer Citation award was presented to Professor Amanda Ellis from Flinders University to recognise the significant contributions she has made to polymer science and technology throughout her career. Amongst many other

things, Amanda has contributed to the polymer community through her role as chair of the RACI Polymer Division in 2014/15 and past-chair in 2015/16.

The penultimate plenary was delivered by Professor Alan Rowan, who has recently moved to Australia to take up the position of Director at the Australian Institute of Bioengineering and Nanotechnology at the University of Queensland. In his talk, Rowan outlined the ways in which polymeric materials could be engineered to display the type of nonlinear mechanics commonly observed in biopolymers and made a case for the importance of this behaviour in interactions between these materials and biological systems, all backed by a solid base of truly advanced materials characterisation.

Finally, the concluding plenary was delivered by Professor Takuzo Aida from the University of Tokyo who gave a lively and engaging snapshot of each of the many varied research topics his group is involved in, from clay nanosheet hydrogels with anisotropic mechanical properties to devices capable of wireless, rudimentary locomotion stemming from light-responsive soft matter incorporated into their design. The breadth of subject matter this presentation covered echoed that of the conference itself and provided it with a fitting end.

In addition to the wealth of fascinating polymer science, the conference also offered a number of excellent networking opportunities, of which the poster session was a personal highlight as an indispensable opportunity to engage with the presenters on the topic of their work. Another key social event was the symposium dinner which, in addition to drawing the conference to a close, offered the opportunity to acknowledge those whose presentations at the conference were truly exceptional. Firstly the Treloar prizes were awarded to those student and ECR researchers who gave oral and poster presentations of particularly high quality. This year the Treloar Oral prize was awarded to William Wong from the Australian National University and the Treloar Poster prize was awarded to Fatemeh Karimi from the University of Melbourne. Following this two Wiley International ECR Prizes were presented to Jan Steinkoenig from Karlsruhe Institute of Technology and Dillon Love from University of Colorado Boulder for the best presentations from international students and ECRs. Finally, Professor Qiao presented Dr. Ian Dagley, CEO of the CRC for Polymers, the Bruce Guise Polymer Science and Technology Award for his major contribution to industrial research in polymer science and/or technology.

In both the quality of science presented and the bringing together of the Australasian and broader polymer community, the 36$^{th}$ APS was undoubtedly a great success and a credit to the hard work put in by its organisers. The Conference convenor Professor Qiao reflected that the APS series has become the “family meeting place” for the Australasian polymer community and their high-quality science and success are the outcome of the constant support of polymer researchers, Ph.D. students and international participants. This year’s instalment upholds the continuously strengthening reputation of this conference and the next two years look set to see the APS grow even further with its incorporation into the RACI Centenary Congress to be held in Melbourne from the 23$^{rd}$ to 28$^{th}$ of July 2017, and beyond that as a part of Macro18 to be held in Cairns in mid-2018.

## 9TH INTERNATIONAL MEMBRANE SCIENCE AND TECHNOLOGY CONFERENCE (IMSTEC), 05/12/2016 - 08/12/2016 - ADELAIDE CONVENTION CENTRE


Prof. Amanda V Ellis
Professor in Chemistry/Nanotechnology & ARC Future Fellow
Flinders Centre for Nanoscale Science and Technology
Flinders University, School of Chemical and Physical Sciences
GPO Box 2100
Adelaide, Australia

27 March 2017

Dear Prof. Jagadish

Thank-you for the funds provided to support travel of PhD students and ECR's to attend the 9th International Membrane Science and Technology Conference (IMSTEC) being held at the Adelaide Convention Centre on the 5-8th December 2016, and encompassed four days of stimulating talks from numerous areas of membrane science, fluid and gas performance materials and surface science. There were approximately 220 delegates from Australia and around the world in attendance, with four plenary, 7 Keynote and 24 invited speakers, five of whom were Early Career Researchers. Also, as is commonly seen at the IMSTEC meetings, there was a large proportion of the session talks being presented by research higher degree students.

The first day started with two workshops (one ECR and one Industry) followed by an opening plenary lecture. The first was from Prof. Sandra Kentish from the University of Melbourne, talking about her work investigating carbon capturing and membranes. The second plenary was given by Prof. Benny Freeman from University of Texas, Austin, and explored the relationship between polymer structure, processing and properties. Prof. Xiao-Lin Wang from Tsinghua touched many aspects such as transport phenomena in charged porous membranes, water treatment and product separation with membrane processes, fabrication of nanoporous polymeric membranes by thermally induced phase separation method, as well as the development of electrochemical materials and processes. Finally Prof. Menachem Elimelech from Yale University finished the conference off with a plenary environmental applications and implications of nanomaterials. There were 7 keynote speakers, Prof, Tony Fane, Prof Eric Hoek, Prof Hideto Matsuyama, Prof Ingo Pinnau, Prof Mathias Wessling, Prof Rong Wang and Prof Suzana Nunes.

# WORKSHOPS, CONFERENCES AND EVENTS

Below are the individuals that received funding from the ANN to attend the conference. This covered all or part of their airfares. All acknowledgment was given to the ANN for these awards.

| | | |
|---|---|---|
| Muayad Nadhim Zemam Al-Shaeli | PhD | Facile Control of Antifouling and Hydrophilicity in BPPO Ultrafiltration Membranes via Diethylenetriamine |
| Yunchul Woo | ECR | Highly performing ion exchange membranes prepared by pore-fillied technique for reverse |
| Andrea Merenda | PhD | Fabrication of novel asymmetric TiO2 nanotube membranes towards photocatalytic membrane |
| James Maina | PhD | Inorganic nanoparticles/ MOFs composite membrane reactors for CO2 separation and conversion |
| Ikechukwu Ike | PhD | The effects of dissolution conditions on the properties of PVDF membranes for water filtration |
| Yaoxin Hu | PhD | The effects of dissolution conditions on the properties of PVDF membranes for water |
| Yaoxin Hu | PhD | Novel 2D Hybrid MOF/Graphene Oxide Seeding for Synthesis Ultrathin Molecular Sieving |
| Meipeng Jian | PhD | Adsorptive removal of arsenic from aqueous solution by zeolitic imidazolate framework |
| Ranwen ou | PhD | Hydrophilic microfiber-polymer hydrogel monolith as forward osmosis draw agent |
| Wang Zhao | PhD | Membrane, Waste water treatment,Nanomaterials,Forward Osmosis |

I would like to sincerely thank you again for your support. This enabled some very talented young scientists to attend our conference and add to its success.

Kind Regards

Prof. Amanda Ellis

## WESTERN AUSTRALIAN SYMPOSIUM OF NANOBIOTECHNOLOGY, 20/12/2016 - 21/12//2016 - UNIVERSITY OF WESTERN AUSTRALIA

### 2016 WA Symposium of Nanobiotechnology

The 2016 WA Symposium of Nanobiotechnology was held over two days at the end of 2016 on the 20th and 21st of December. The symposium was a great success with just under 100 attendees across the 2 days (Figure 1). Day one consisted of talks from both international research scientists such as Prof. Shankar Balasubramanian from the University of Cambridge and Prof. Lawrence Hurley from the University of Arizona as well as a number of exciting research talks from some of the leaders of nanobiotechnology in Australia. Students and Early Career Researchers (ECRs) weregiven a chance to compete for cash prizes in a 3-minute thesis style competition on day two, with the funding for the prizes generously provided by the Australian Nanotechnology Network (ANN) (Figure 2).

***Figure 1 -*** *Group photo of a number of the attendees at the 2016 WA Symposium of Nanobiotechnology*

Day two also provided attendees with a unique opportunity for professional development. A panel discussion where our speakers provided a fantastic insight into their thoughts and personal accounts with regards to career progression and successfully navigating the PhD/ECR period of their careers. In the afternoon on day two a number of speakers were handpicked to discuss important topics for emerging scientists such as science communication, leadership in science, patent law, intellectual property and social media in science as well as looking at ways to engage further with society, the community through research.

The research aspect of the symposium was a fantastic event and so was the symposium dinner hosted at the University Club on the banks of the Swan River.

**Figure 2 -** Australian Nanotechnology Network (ANN) 3-minute thesis competition award winners. Clockwise from top left, 1st placed PhD Student Lisa Belfiore University of Wollongong, 2nd placed PhD Student Michelle Nguyen– University of Western Australia, People's Choice Award (voted by the entire audience) Amlan Chakraborty – Monash University and 1st placed ECR Award – Gino Putrino – University of Western Australia

The dinner had a sponsored 'Mixer' supported by John Morris and a festive theme being so close to Christmas (Figure 3). A quiz night was the entertainment for the evening and all those who attended had a great time with fantastic food, company and trivia.

**Figure 3** – Some of the speakers from the symposium enjoying the John Morris Mixer prior to the dinner. From left to right: Julianah Hamzah, David Sampson, Tim St Pierre, Shankar Balasubramanian and Roey Elnathan.

We would like to thank the funding from all our major sponsors (see below) but especially the ANN where their funding went directly to covering the registration cost of ANN PhD/ECR members to attend the symposium as well as supporting the 3-minute thesis style prizes.

With thanks,

The Organising Committee of the 2016 WA Symposium of Nanobiotechnology
Tristan Clemons, Iyer Swaminathan, Nicole Smith ,Cameron Evans.

# Website

http://www.ausnano.net

The ANN Website is a very popular website and as at the end of 2016 it received more than 10,888,000 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.

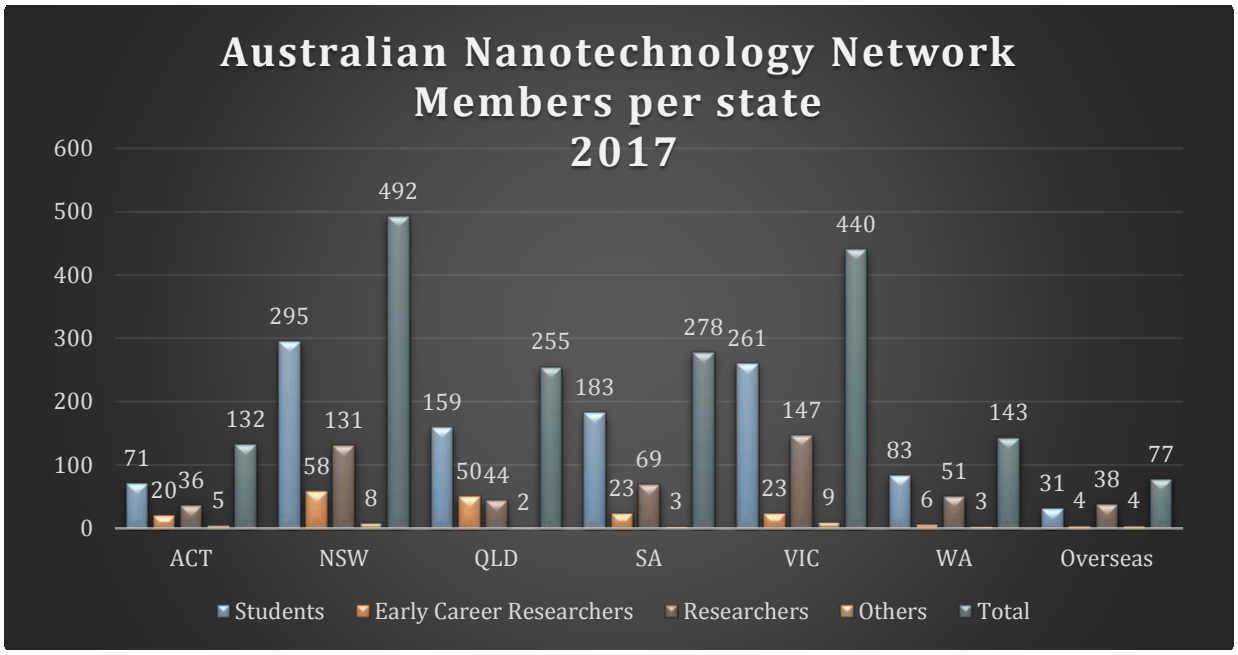
Website contains among other things:

- 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.

# 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 industry.




| State | Students | Early Career Researchers | Researchers | Others | Total |
|---|---|---|---|---|---|
| ACT | 71 | 20 | 36 | 5 | 132 |
| NSW | 295 | 58 | 131 | 8 | 492 |
| QLD | 159 | 50 | 44 | 2 | 255 |
| SA | 183 | 23 | 69 | 3 | 278 |
| VIC | 261 | 23 | 147 | 9 | 440 |
| WA | 83 | 6 | 51 | 3 | 143 |
| Tasmania | 2 | | | | 2 |
| Overseas | 31 | 4 | 38 | 4 | 77 |
| TOTAL | | | | | **1819** |

# Planned 2017 Activities

## January

**8th Biennial Australasian Colloid and Interface Symposium.**

*29/01/2017 - 02/02/2017* - **Coffs Harbour**

The eighth biennial Australian Colloid and Interface Symposium organised jointly by Flinders University and the Australian National University with support from ACIS will be held at Opal Cove Resort, Coffs Harbour, New South Wales, Australia from 29 January to 2 February 2017. This international four-day conference (plus Sunday Welcome reception), will provide an excellent opportunity for international and local colloid, surface and interface scientists to meet and discuss recent developments in their areas of research.

## May

**11th Conference on New Diamond and Nano Carbons.**

**2***8/05/2017 - 01/06/2017* - **Shangri-la, Cairns**

The 11th International Conference on New Diamond and Nano Carbons 2017 will be held in Cairns, Australia on the shore of the Great Barrier Reef. The conference spans wide research topics from fundamental physical and chemical concepts to applied technologies.

## July

**7th International Conference on Nanomaterials by Severe Plastic Deformation.**

**02/07/2017 - 07/07/2017 – Sydney**

The NanoSPD conferences have been an important series of international events highlighting the potential of severe plastic deformation as a tool for producing bulk nanostructured and ultrafine grained materials.

**Nanotechnology Entrepreneurship Workshop for Early Career Researchers.**

*12/07/2017 - 13/07/2017* - **Future Industries Institute, Mawson Lakes Campus, University of South Australia**

The aim of this workshop is to provide a forum for early career researchers (ECRs) and postgraduate students working on nanotechnology research to interact with industry leader and learn about how to commercialise Nanotechnology

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