# NANO Q

BIG SCIENCE MEETS THE VERY SMALL

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Issue 3

Australian Research Council Nanotechnology Network

Australian Government
Australian Research Council

# Welcome

## by Professor Chennupati Jagadish

### Convenor of Australian Research Council Nanotechnology Network

Welcome to the third issue of Nano Quest (NanoQ). The purpose of NanoQ (two issues per year) is to highlight recent developments in the field in Australia and also to provide information of interest to policy makers and the public. There has been a significant amount of public interest in nanotechnology with reports in the media creating hype as well as scare. Enhancing public awareness of nanotechnology is important for the acceptance of the technology by the wider community while addressing issues of public concern in terms of health, safety and environment.

The Australian Nanotechnology Network (formerly ARC Nanotechnology Network) is continuing its operations with support from Australian Government Department of Innovation, Industry, Science and Research. Network name is changed to reflect this change of funding source and also to encourage participation of industry in the Australian Nanotechnology Network (ANN) activities in addition to participation of the research community. ANN's flagship conference, International Conference on Nanoscience and Nanotechnology (ICONN), will address various issues including manufacturing, occupational health and safety, standards, regulation, ethics, social impact, environmental effects etc. ICONN 2012 will be held in Perth during Feb 5-9, 2012.

This issue of NanoQ features how the nanotechnology is used in the development of bio- fuel cells which convert directly chemical energy into electrical energy. Renewable energy sources are becoming increasingly important and an article is featured on low cost wet chemistry methods to obtain nanocrystal based solar cells. Nanoscale biological and chemical sensors are being developed for a broad range of sectors and an article on this subject is featured in this issue. Another article features how nuclear reactors could be used to study nanoscale materials. Finally, an article on an innovative book project showcasing Nanotechnology in Australia (published by Pan Stanford) with all authors being PhD students and early career researchers is featured developing valuable writing skills of our next generation of nanotechnology researchers. Book project was carried out under the mentorship of Deb Kane (MqU), Adam Micolich (UNSW) and James Rabeau (MqU).

If you would like to submit an article for consideration for publication in NanoQ, this needs to be written at a level which is easily accessible to the wider readership with no background in nanotechnology. Please submit these articles to Ms. Liz Micallef, Manager, Australian Nanotechnology Network. Also, if you are a reader interested in learning more about a particular area of nanotechnology and would like to see an article published in NanoQ, please contact Liz. We will do our best to feature articles of public interest. If you would like to receive a personal copy of NanoQ or would like to provide feedback on NanoQ, please contact Liz.

Enjoy the Third issue of NanoQ

# NANO NEWS

## July 2011

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# What to do When Your Reactor Goes Critical

## Investigations of the very small using tools that are reasonably large

by Professor Michael James

When the first platypus was sent back to Britain by European settlers in 1799 and examined by naturalist Dr George Shaw, his initial reaction to this bizarre creature was that it was an elaborate hoax. The lack of stitches holding the bill onto the pelt puzzled him though… The platypus is one of the most unusual of living creatures: a mammal which has fur and suckles its young; lays eggs; has webbed feet, a duck-like bill and a tail like a beaver. Males have a poisonous spur on their hind legs which can cause excruciating pain. So odd is this creature that its very existence has become a focal point in the evolution versus creationism debate.

Well if you think Dr Shaw found the composition of the platypus puzzling; take your mental image of our cute, secretive national icon, stretch it 10 metres; replace its fur by concrete, boron carbide, lead and stainless steel; beef it up to a hefty 90 tonnes; put all of its vital organs under vacuum and feed it a constant diet of cold neutrons. To my knowledge, nobody has ever referred to the Platypus time-of-flight neutron reflectometer (Figure 1) at the Australian Nuclear Science and Technology Organisation as "cute", but its bizarre anatomy does strike a chord with its creek-dwelling cousins.

*Figure 1. The Platypus time-of-flight Neutron Reflectometer*

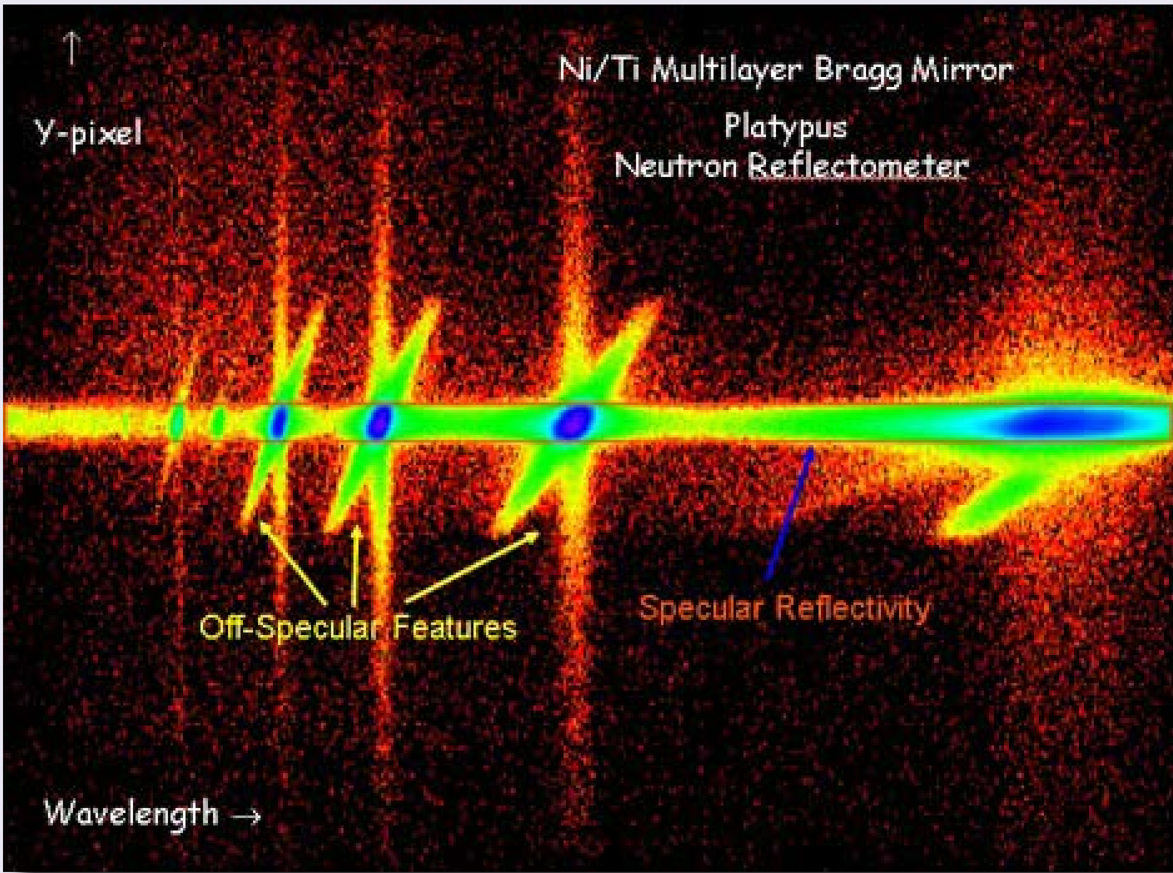


*Figure 2. Platypus neutron reflectivity data from a Ni/Ti Bragg mirror.*

Platypus is one of the initial seven operational instruments as part of the international user facility at Australia's new 20 MW OPAL research reactor; overall the largest single investment in scientific infrastructure that this country has ever seen. More than seven years in the making, and costing about the same as some Hollywood blockbusters, Platypus and its big brother Quokka (the Small-Angle Neutron Scattering instrument) dominate the sky-line of the Bragg Institute's neutron scattering facility at Lucas Heights in Sydney. In concert with our X-ray reflectometer and two SAXS instruments just metres away, we have established one of the best suites of instrumentation for the study of nanoscale materials and processes.

In contrast to the other instruments at OPAL which use single wavelength neutron beams, Platypus is a white-beam reflectometer that uses the entire neutron energy spectrum.1 Boron-coated carbon fibre discs are the heart of Platypus and chop the continuous stream of cold neutrons into pulses that beat through the instrument every 43 milliseconds. The flexibility of our disc chopper system also allows us to boost the neutron flux of Platypus by a factor of 7 times and conduct rapid, time-sensitive experiments. The role of Platypus is to study nanoscale thin-films (1 – 300 nm), surfaces and interfaces, as well as physical, chemical and biological processes that occur on the nanoscale with essentially atomic resolution. The penetrating power of the neutron means that metallic, inorganic and molecular films can be studied at the air-solid, air-liquid and solid-liquid interfaces. The ability to selective deuterate nanoscale components of samples such as surfactants, polymers, phospholipids and biological molecules (available from the NCRIS funded National Deuteration Facility) is a key aspect that dramatically enhances the precision and sensitivity of the technique. Early published results from Platypus include: microphase separation in diblock copolymer films;2,3 explosive sensing dendrimer films;4 diffusion processes in organic solar cells5 and organic light emitting diodes;6 molecular adsorption on self-assembled monolayers;7 studies of anti-biofouling surfaces;8 interfacial behaviour of DNA;9 and interactions between cubic phase nanoparticles (cubosomes) and biomimetic membranes.10

The final twist in Platypus' evolutionary tale is the implementation of its neutron polarization capability with low temperature and high applied magnetic fields at the sample, for the study of spintronics and thin-film magnetic memory. The nuclear spin of the neutron makes it one of the best probes of magnetic materials and combined with the extremely high spatial resolution available from Platypus generates a capability that will lead to world-class magnetic thin-film research.

Visitors to Perth and the South-West of Western Australia may be familiar with Quokka, a close marsupial relation to the wallaby. Dutch explorers towards the end of the 17th century may have mistaken them for large rats, but only the criminally insane could confuse a small, dumpy kangaroo with the 40 metres long beast that occupies most of OPAL's Neutron Guide Hall. Quokka has been built for investigations of bulk nanoscale systems such as protein structures in solution, polymers, liposomes, surfactants and emulsions, nanoparticles and nano-porosity. The wavelength band used in Quokka is selected from the cold neutron spectrum by spinning a neutron adsorbing turbine in the beam at speeds approaching 30,000 rpm. Only those neutrons with the correct velocity can pass through the turbine vanes and into the rest of the instrument.

Although structures studied using Platypus are mostly 1-dimensional (normal to the surface of the film) and those studied by Quokka are 3-dimensional, both instruments rely on very precise measurement of the change in momentum of the neutron following a scattering event. Furthermore, the capacity to see "large-scale" thin-film or bulk structures (up to hundreds of nanometres in size), requires excellent sensitivity and the ability to detect scattered neutrons at very small angles with respect to the incident beam. In the case of Quokka, this is achieved by placing the detector as far away from the sample as possible – with a bit of shoe-horning we managed to squeeze our desired detector vessel into the building.

Construction of these neutron scattering tools has truly been a multi-national affair. Aside from the obvious infrastructure (the reactor from Argentina, the cold neutron source from St Petersburg and the supermirror neutron guides from Budapest which allow us to build a diverse suite of instruments around OPAL), each instrument is a manifestation of "globalization" in the best sense of the word. Precision motion stages from France, neutron detectors from the US and Germany, locally produced shielding, vacuum vessels and control electronics, neutron optical elements from Switzerland, neutron polarization systems from Hungary, and the disc chopper and

*Photo by Dave Watts*
*State of the Environment (SoE) Tasmania*

*Quokka, Melbourne Zoo*
*sourced from Wikimedia Commons*

velocity selector systems also from Germany. Mix this up with home-grown scientific and engineering design, mechanical, electrical and computing effort and you have before you these wonderful (yet curiously ugly) examples of Australian native fauna.

Aside from building and operating these neutron and X-ray scattering facilities for the scientific community, the Bragg Institute hosts more than 60 research staff and students; approximately a quarter of whom use small angle scattering or reflectometry as techniques central to their work. The range of research areas are diverse (and not limited to) complex fluids, biological membrane structure and function, photochromically active surfaces, electrochemistry, protein conformation and protein complexes, food science, the nanoscale physics of superconductors, hydrogen uptake in metals, polymer functionalised surfaces, emulsions, molecular self-assembly and spintronic devices.

Both Platypus and Quokka are available for domestic and international researchers (free-of-charge). Allocation of beamtime is based on scientific merit (determined by the review of beamtime proposals by international experts); however I am sure that we will gladly accept hard currency for commercially sensitive research.

If you would like further details, try our website: http://www.ansto.gov.au/research/bragg_institute


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# Biofuel Cells

by Shannon Little

The increasing adoption of portable devices requiring mobile power supplies has resulted in a significant dependence on battery technologies. However, the batteries currently in commercial use often contain toxic, acidic and/or flammable constituents that require sturdy protective casings in order to protect them from the outside environment. Significant scope thus exists for new power technologies that are more environmentally friendly and that are able to be housed within more lightweight and flexible casings.

A fuel cell is a device similar in design to that of a battery in that it is comprised of two electrodes, an anode and a cathode, enclosed within a vessel containing an electrolyte. However, while a battery's fuel is contained wholly within the cell housing itself and is recharged via application of an external charge, a fuel cell operates by feeding the fuel into the cell as required with the subsequent removal of spent fuel products. While there are many different types of potential fuel sources available, fuel cells that utilise enzymes to catalytically convert environmentally friendly biofuels, such as glucose, into electricity have received much research interest. This is in part due to the diversity and abundance of fuel substrates that are able to be catalytically decomposed by enzymes which allows for a diverse array of possible energy generation strategies to be explored.

A biofuel cell can broadly be defined as a fuel cell that is able to directly convert chemical energy into electricity via a biochemical pathway. The biochemical pathway in this sense refers to using a biocatalyst, such as a whole living organism (microbial), or enzymatic or non-enzymatic protein, to catalyse the reduction and/or oxidation of a fuel substrate. A schematic of a simple enzymatic biofuel cell configuration utilising two well-known biocatalytic enzymes, glucose oxidase and bilirubin oxidase, is shown in Figure 1. The cell is comprised of an anode at which electrons are transferred from the bio-catalyst to the electrode and a cathode at which electrons are accepted from the electrode. In Figure 1, the anodic side of the cell utilises glucose oxidase (GOx, Figure 2(a)) to catalytically oxidise the fuel (in this case the sugar, β-D-glucose, Figure 2(b)). The enzyme obtains two electrons from the glucose which are subsequently transferred to the anode with the help of an electron shuttling molecule, ferrocenemethanol (FcMeOH). The electrons then flow through an external circuit to the cathode, driven by an electromotive force arising

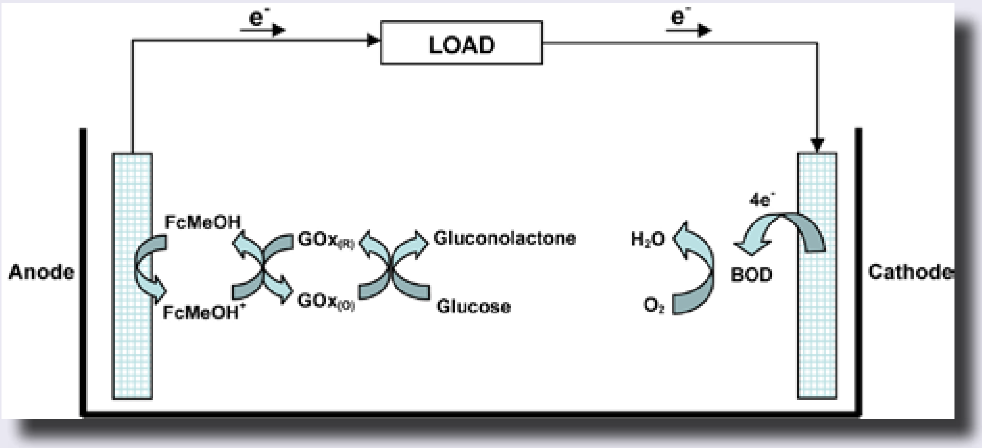



*Figure 1: Schematic of a biofuel cell used to convert a fuel (glucose) to electricity.*

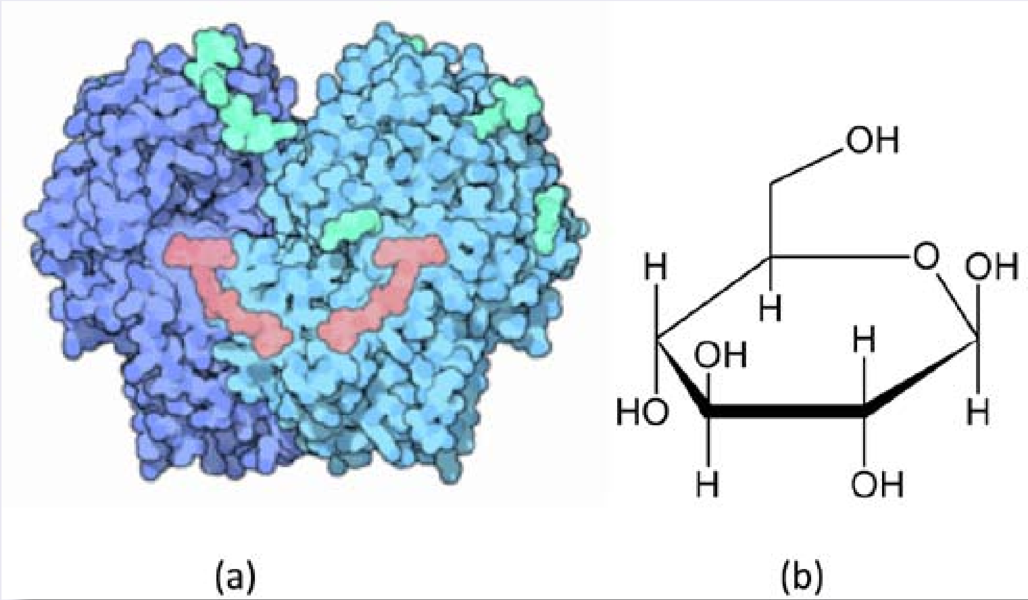



*Figure 2: (a) glucose oxidase (GOx) and (b) β-D-glucose. GOx illustration by David S. Goodsell, RCSB PDB 77-1.*

from the potential difference between the two electrodes, where they are able to do useful work. The cell is completed by a cathodic type enzyme, in this case, bilirubin oxidase (BOD), which accepts electrons from the cathode so that it can perform the biocatalytic reduction of molecular oxygen to water. One could envisage the advantages of using such a reaction system to produce electricity - imagine recharging your phone instantaneously using just a few millilitres of cheap, environmentally friendly sugar solution!

One of the more exciting areas of biofuel cell research has been toward in vivo applications-that is, the integration of biofuels cells within the human body. Such fuel cells are able to utilise naturally occurring fuels found within the bloodstream, such as the afore mentioned sugar β-D-glucose, to power devices. Such cells can be envisioned to eventually replace the current external power supplies associated with, for example, devices such as the cochlear ear implant which currently rely on bulky, external power packs. Recent literature reports have demonstrated the ability of biofuel cells to operate under the blood glucose concentrations typically found within human blood (~5 - 8 mM). Mano et. al. utilised the enzyme GOx and an oxygen-reducing enzyme, laccase, in a biofuel cell that was able to produce 280 $\mu$W.cm-2 using only a 5 mM concentration of glucose, and up to 398 $\mu$W.cm-2 using a slightly higher glucose concentration of 12 mM Nicolas Mano [1]. Similar power densities of 315 $\mu$W.cm-2 were reported under physiological conditions (20 mM phosphate buffer, pH 7.24 containing 0.14 M NaCl) at a glucose concentration of 15 mM using the enzymes GOx and BOD electrically wired to carbon fibre microelectrodes [2].

Despite these impressive results, if biofuel cell devices are to become viable alternatives for useful power production, new electrode materials are required that are able to produce more substantial current densities whilst still being able to be integrated within the ever-shrinking size of current devices. This issue is currently being addressed by employing high surface area electrodes that have nanostructured surface architectures. Such electrode platforms allow for significantly more electroactive material to be deposited onto them which in turn results in significantly higher current densities being able to be produced. For example, Flexer et. al. utilised novel carbonaceous foams to provide a high surface area matrix at which to immobilize catalytic enzymes [3]. The high surface area substrate produced current densities that were 13 times greater than those obtained using more conventional electrodes. Even more recently, hierarchically structured electrodes comprised of a macro-porous scaffold having a nanostructured topography were reported [4]. The nanostructured surface of the electrode in this case was comprised of an entangled web of carbon nanotubes that allowed for significant amounts of catalytic material to be effectively supported (Figure 3). The combination of the high surface area nanostructured surface and macro-porous scaffolding resulted in significant power densities owing to the high enzyme loading and superior mass transport of fuel to the electrode surface.

Whilst the incorporation of a functioning biofuel cell within the body will require further research efforts, particularly in engineering the interface between biology and electronics, there is clear evidence of ongoing improvements in enzymatic fuel cell design and real prospects for their commercialisation. The production of new nanostructured electrode materials is likely to play a significant role in the development process and will likely lead to the generation of biofuel cells able to produce useful energy from readily available and environmentally friendly biofuels in the near future.

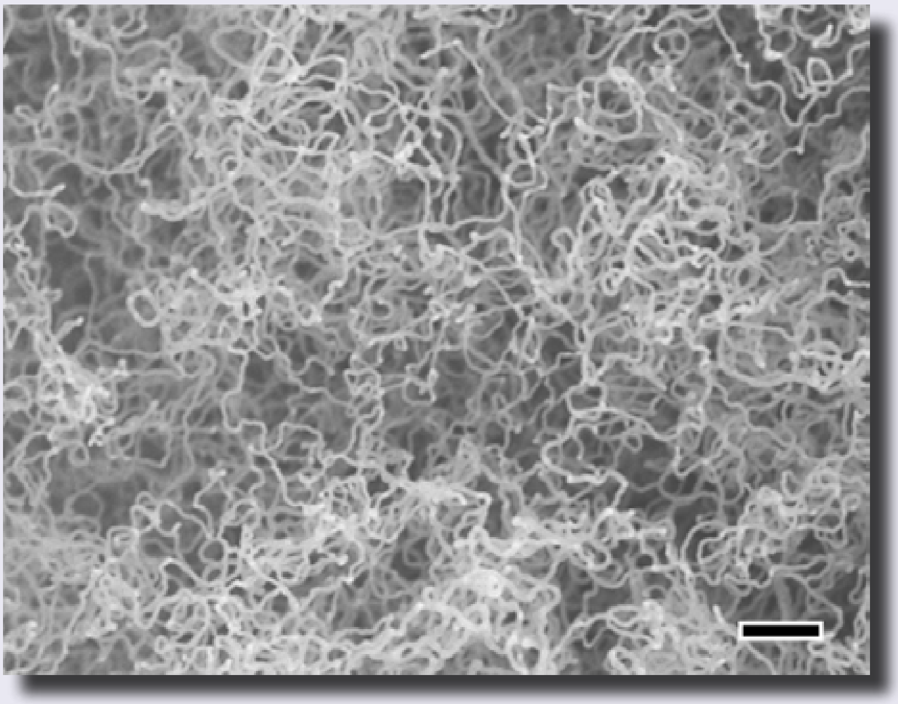
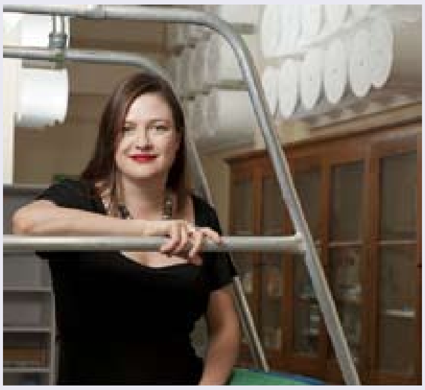


*Figure 3: The nanostructured material comprising of an entangled web of carbon nanotubes that was used by researchers to produce high power-density biofuel cell electrodes. Scale bar in the lower right corner represents 1μm.*

**Shannon Little** completed a PhD through University of Wollongong's Intelligent Polymer Research Institute in August 2010. He is currently working in a post-doctoral position at the Centre de Recherche Paul Pascal, CNRS in Bordeaux, France, focussing on producing conductive and transparent electrodes under the supervision of Prof. Phillipe Poulin.



# Sensing on the Nanoscale

## Optical fibre nanorail dip sensors for wine, water, corrosion and reproductive health

by Tanya Monro

There is a huge demand for very sensitive sensors that can measure chemicals or biomolecules in nanolitre volumes for applications in the medical diagnostic, mining, defence and agriculture industries to name just a few. Professor Tanya Monro, the Director of the Institute of Photonics & Advanced Sensing (IPAS) at The University of Adelaide, has been leading the development of a new class of chemical and biological nano sensors that solves this challenge.

One of leading areas of IPAS research is the development of microstructured optical fibres. One of the simplest and most versatile form of microstructured fibre is the suspended nanorail, which combines the optical properties of a nanowire with the practical characteristics of an optical fibre.

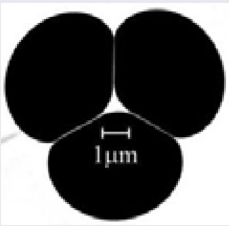



*Figure 1*

**Figure 1** shows an electron micrograph of one of our suspended nanorail dip sensors. At the core of this technology is a nanorail that guides a light beam down its longitudinal axis. If the nanorail is comparable to or smaller than the wavelength of the light then it can no longer be confined and spreads into the air spaces surrounding it.

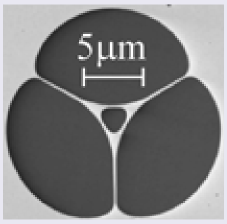



*Figure 2*

**Figure 2** shows the distribution of the light guided by the optical nanorail. By functionalising the surfaces within the optical fibre with chemical fluorophores or antigens it is possible to detect the presence of chemical or biological molecules of interest. For example, one exciting recent development of this platform was the demonstration of the specific detection of aluminium ions in solution in a suspended nanorail in which the internal air-glass surfaces were functionalized with a novel surface-attached fluorophore capable of changing its fluorescence in response to the concentration of aluminium ions. It is the first demonstration of chemical sensing on the nano-litre scale. This result, which exemplifies the capacity of nanofabrication technologies to advance science and technology that straddles the discipline boundaries (in this case optical physics and synthetic chemistry), was published in Langmuir in April 2011.

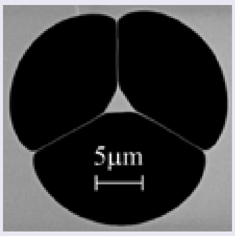



*Figure 3*

**Figure 3** shows a fibre being dipped into a liquid sample. The liquid to be examined can be analysed by being drawn into the voids within the fibre by capillary action. An additional benefit of this architecture is that the light source and the detector can be located at the same end of the fibre as the fluorescent signal is backscattered up the same nanorail.

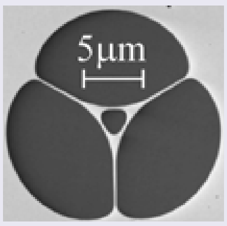



*Figure 4*

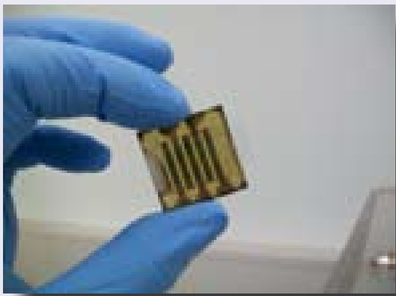
**Figure 4** shows a recent development of the dip sensor platform, which has 3 nanorails. We anticipate this will increase sensitivity further by allowing us to cancel out the fluorescence inherent in the glass by having separate source and detector rails.

IPAS is working with a wide range of end users from DSTO to major wine producers and reproductive health companies who all have applications for these new sensors.

Our current achievements with these sensors include sensing of chemical concentrations of less than 10pM and also the use of sub-10nl volume samples.

# Nanocrystal Solar Cells via Sol-Gel Technology

Brandon I. MacDonald, Jacek J. Jasieniak, Anthony J. Morfa, Paul Mulvaney

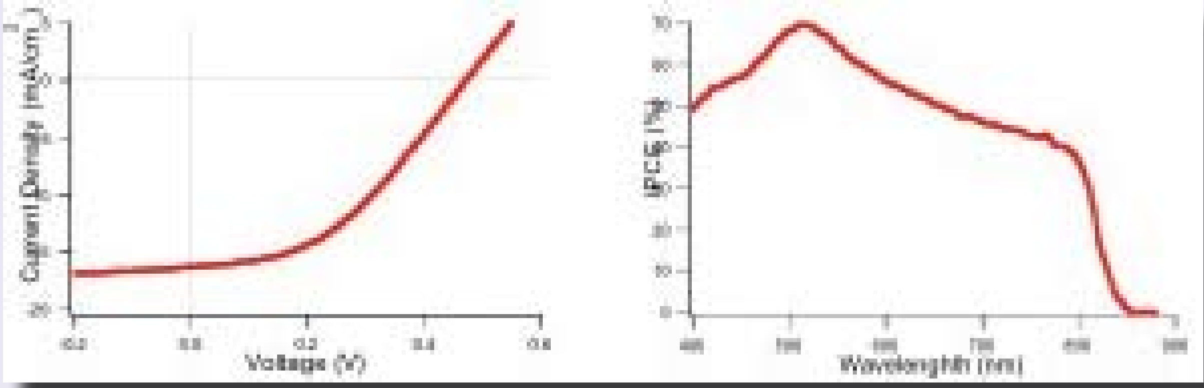


**Left:** *A solution of CdTe nanocrystals.* **Right:** *A completed device with Al metal contacts. The total thickness of the nanocrystals and the Al is 300nm.*

Solar energy is a cheap, abundant and renewable energy resource. While many current solar cell technologies do convert solar energy into electricity, they operate at an overall cost that is several times more expensive than that of conventional sources such as fossil fuels. One way to potentially reduce these costs is to develop cells which are fabricated from solutions of nanoparticle inks. Advantageously, these cells use very little material, as they are only a few hundred nanometers thick, as opposed to several microns for typical silicon and thin-film solar cells and they can be printed. These factors create the opportunity to eventually use such inks to develop printed solar cells on a roll-to-roll basis, similar to the way newspapers are printed.

The Nanoscience Lab (NSL) at the University of Melbourne, led by Prof. Paul Mulvaney, in strong collaboration with CSIRO, is researching these solution-based devices using cadmium telluride (CdTe) nanoparticles as a model system. CdTe is typically a p-type semiconductor with a direct optical bandgap of 1.4eV in bulk form and a high molar extinction coefficient. Both of these properties are ideal for a solar cell with a single light absorbing layer. CdTe is also a proven solar cell material, having demonstrated power conversion efficiencies of up to 16% using growth methods such as close space sublimation and chemical vapour deposition. The NSL and CSIRO hope that similar results will eventually be achievable using nanoparticle inks.

To synthesize the CdTe nanoparticles a room temperature tellurium containing solution is rapidly injected into a cadmium containing solution at 260$^{o}$C. The resulting supersaturation causes a burst of nanoparticle nucleation. This is followed by a lower temperature heating step which allows the particles to grow in size up to approximately 4nm. The nanoparticles are then washed to remove any unreacted precursor material and dispersed in a lower boiling point solvent which can evaporate during the deposition process. To fabricate a solar cell, the nanoparticle solution is spin-cast onto a conducting glass substrate, the hole-collecting contact, to give a thin, uniform nanoparticle film. The film is then exposed to a solution of CdCl2 and annealed at 300-400$^{o}$C. This heating step serves two purposes. First, it removes the organic ligands surrounding the nanoparticles, bringing them into




**Left:** *A current-voltage curve used for measuring device efficiency. This device exhibits 3.2% power conversion efficiency.*
**Right:** *An IPCE spectrum for the same device showing maximum performance near 500nm.*

closer contact. Secondly, it causes the particles to grow, a process that is facilitated by the CdCl2. This final process reduces the number of grain boundaries in the film, thereby drastically enhancing its electrical properties. Finally, the device is completed by thermally evaporating 100nm of aluminium, which serves as the electron-collecting contact.

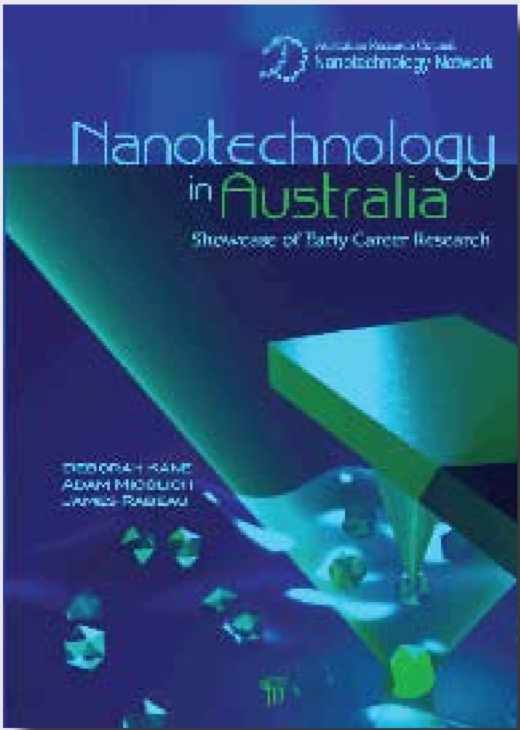
The completed devices are then placed under a solar simulator and subjected to current-voltage sweeps to measure their power conversion efficiency. Incident photon conversion efficiency (IPCE) measurements allow the performance to be measured as a function of the incident light wavelength. Devices so far have exhibited power conversion efficiencies up to 3% with IPCE maxima of 70% with incident light at 500nm. These results are on par with the best reported efficiencies to date for nanoparticle based solar cells.

For this type of solar energy technology to be commercially viable the power conversion efficiency must approach 10%. While we are still some way off this milestone, our current efforts in trying to understand the material properties and photo-physics of these systems, as well as developing novel device architectures, place this goal within reach.

*This research is sponsored by the ARC. BM would like to acknowledge support through the University of Melbourne MIFRS and MRS scholarships as well as a CSIRO studentship.*

# ARCNN Book Project

## A Showcase of Nanotechnology Research and Writing of PhD Students and Early Career Researchers in Australia




*Reprinted with permission from Nanotechnology in Australia: Showcase of Early Career Research, edited by Deborah Kane, Adam Micolich, and James Rabeau, Pan Stanford Publishing, June 2011, 440pp (US$129.95, ISBN 978-981-4310-02-4 [hardcover], 978-981-4310-03-1 [eBook]), www.panstanford.com*

The book shown is the culmination of a project developed and supported as an activity of the Australian Research Council Nanotechnology Network (ARCNN) in partnership with the Nanotechnology specialist publisher Pan Stanford. One of the key aims of the research network is to support professional and research skill development in postgraduate research students and early career researchers. As an innovation in postgraduate/ postdoctoral research skills and networking education, this book has been produced to a format designed to achieve this.

Chapter first authors were selected by a process that ranked their expressions of interest. They wrote a draft of their chapter ahead of a nine day on-campus workshop held at Macquarie University, Sydney. Each of the three editors was assigned four chapters. This defined three working groups. Within each group, two participant reviewers were assigned to each chapter in addition to the editor.

The main focus of the first two days of the workshop was for participants to act as reviewers of the writing of others. They did this after being pre-conditioned to have heightened awareness of writing structure and quality, engendered through presentations and informational handouts on quality scientific writing. This, in turn heightened their sensitivity to their own writing style and quality when they returned to their own chapter on day 3 of the workshop. They had three annotated reviews of their chapter at that stage.

The participants were also coached on the importance of the visual impact of figures and graphics in their chapter. A motivating hook was *“How do you get your research onto the front cover of Nature Nanotechnology or Small?”* To introduce the participants to a new skill in 3-D graphics, a tutorial on *“Introduction to Blender and Luxrender”* was given on day 2 by Iwan Kartiko, a specialist in using this software. Expert support to assist learning and using this software was provided throughout the workshop.

By day three there was enormous anticipation of the feedback to be received. There was aheightened energy in the workshop room on day 3. Everyone was geared up to get on with improving their chapter. The remainder of the workshop saw the participants hard at work improving the writing and visual presentation of their chapter. Additional presentations addressed issues of copyright and authorship, and using mind maps to plan research and writing. Overall, the workshop involved intense work, carried out within a relaxed and positive group atmosphere. The success of the project relied in large part to the constructive and supportive group dynamic that prevailed.

The feedback from the participants on this book project affirms that the opportunity to participate has been of particular value to postgraduate students, late in their candidature, and to early career scientists that have recently completed postgraduate studies.

The research areas covered in the book reflect many of the research strengths in Australian nanotechnology. Australia has a long tradition in optics, optoelectronics and photonics which has seen research in nanophotonics grow in a natural way. Chapter 1 (Dr Kristy Vernon) and chapter 2 (Dr Fiona Beck) describe two different programs in plasmonics research – the first reporting primarily theoretical design of plasmonic circuit elements, the second on improving infrared light trapping in solar cells using layers of metal nanoparticles of optimized design. Chapter 3 (Dr George Yiapanis) is on theoretical nanoscale design of self-cleaning coatings. It describes modeling the chemistry, morphology and stability of the surface to show the interdependencies involved in creating a surface that resists the adhesion of contaminant particles.

There is a strong focus on nanomaterials in the book. This reflects the large materials science community, in part supporting and supported by Australia's booming mining industries. Australia holds many of

## Participant's Feedback

*"The ARCNN book workshop challenged me to give my opinion on the writing of others and accept the opinion of others about mine. It exposed me to research of other early career researchers from around the country. It provided me with the opportunity to learn new skills with tutoring in graphics software.*

*The process was good practice at meeting deadlines.*

*It will be a rewarding experience to see the book come together."* **- Kelly Bailey, ECR**

*"The workshop was thoroughly enjoyable and the feedback I received from the editors and other authors was extremely helpful. The opportunity to develop my writing skills for a more general readership was very rewarding and I would highly recommend this workshop to others."*

**- Matt Carroll, PhD Student/ECR**

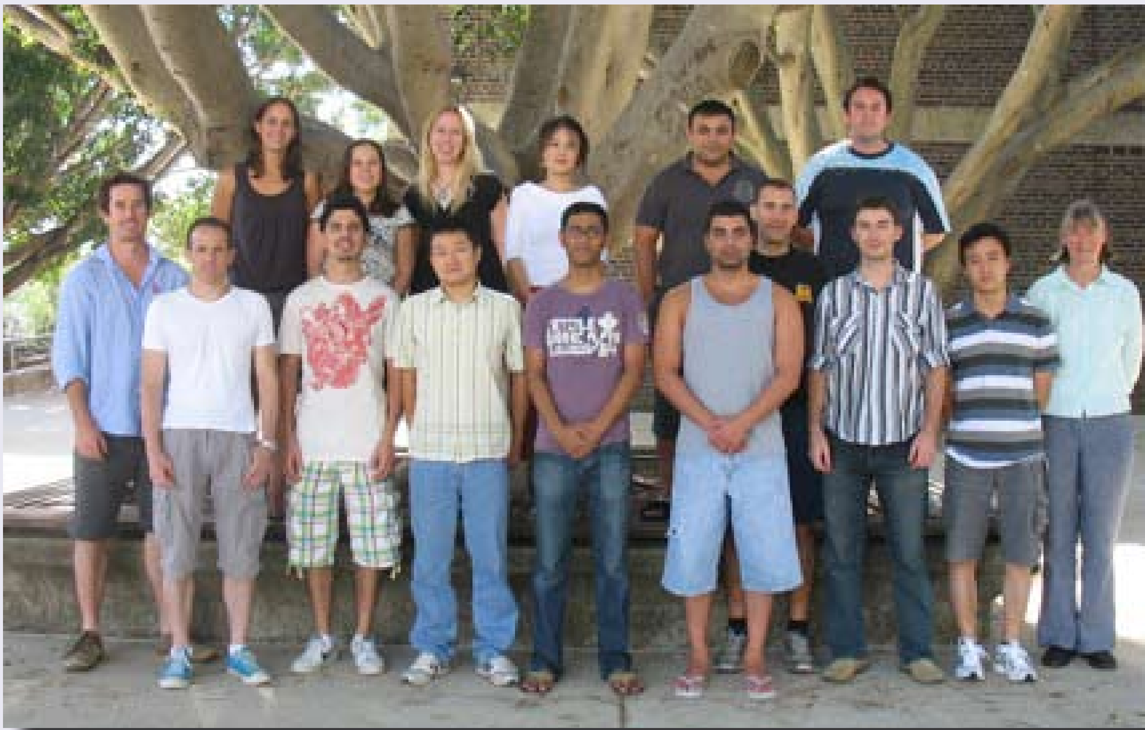
*"This workshop will be of great benefit to all early career researchers! I learnt valuable scientific writing skills that are not only valuable to my book chapter, but to journal papers as well. The structure of how to write a journal paper was of particular interest to me, as well as how to write catchy titles, achieve good image quality and how to keep a reader entertained.*

*The hands-on aid with developing figures was particularly useful!'* **-Kristy Vernon, ECR**

*"The ARCNN Book Workshop was a unique experience which I enjoyed immensely. Thought provoking, challenging, exciting and always fun, I strongly recommend ECRs to participate in this once in a lifetime opportunity.*

*I've learnt a great deal during this workshop in regard to scientific writing, editing/reviewing, graphical imaging and the publication process."*

**-George Yiapanis, PhD student**



*Workshop group photo, Macquarie University, Sydney. Back row (left to right): Kelly Bailey, Fiona Beck, Kristy Vernon, Wei Deng, Matt Carroll and Adam Joyce. Front row (left to right): Jim Rabeau, Adam Micolich, George Yiapanis, Dayong Jin, Mushtaq Sobhan, Mohammad Choucair, Carlo Bradac, Alexey Glushenkov, Jian Liu and Deb Kane.*

the world's major mineral and metal deposits and research that leads to value-added manufacturing in this sector is a priority. Australia is contributing strongly to the world effort on nanodiamond research. One groups' research is described in Chapter 4 (Carlo Bradac). Chapters 5 – 8 discuss production and applications of nanoparticles of various materials. Vanadium compound nanorods for electrochemical energy storage (Dr Alexey Glushenkov), metal nanoparticles produced by laser ablation (Mushtaq Sobhan), hollow silica nanoparticles produced by chemical synthesis methods (Dr Jian Liu), and bulk synthesis of graphene (Dr Mohammed Choucair), are described sequentially in these four chapters. Chapter 9 also covers production of superparamagnetic nanoparticles to be used as MRI contrast enhancing agents (Dr Matt Carroll). It bridges the research topics into nano-bio-medical subjects.

The final three chapters are on nano-bio-medical science. Chapter 10 discusses luminescent nano-bioprobes for bioassays and bio-imaging (Dr Dayong Jin). Chapter 11 discusses using nanomorphology of metal nanoparticles to achieve enhanced fluorescence (Wei Deng). Last, but certainly not least, Chapter 12 describes advances in biomimicry of olfactory biosensing, in a sense creating an artificial nose (Dr Kelly Bailey).

The chapters collectively represent a sample of Australian nanotechnology research. The chapters give interesting contrasts in physical and chemical approaches to nanoparticle production and characterisation. The multi-disciplinary nature of nanotechnology is well illustrated with the chapters showing nearly all combinations of physics, chemistry and biology in their subject matter.

*ARCNN Book Workshop in action, Department of Physics, Macquarie University, Sydney. Reprinted with permission from Nanotechnology in Australia: Showcase of Early Career Research, edited by Deborah Kane, Adam Micolich, and James Rabeau, Pan Stanford Publishing, June 2011, 440pp (US$129.95, ISBN 978-981-4310-02-4 [hardcover], 978-981-4310-03-1 [eBook]), www.panstanford.com* http://www.ausnano.net