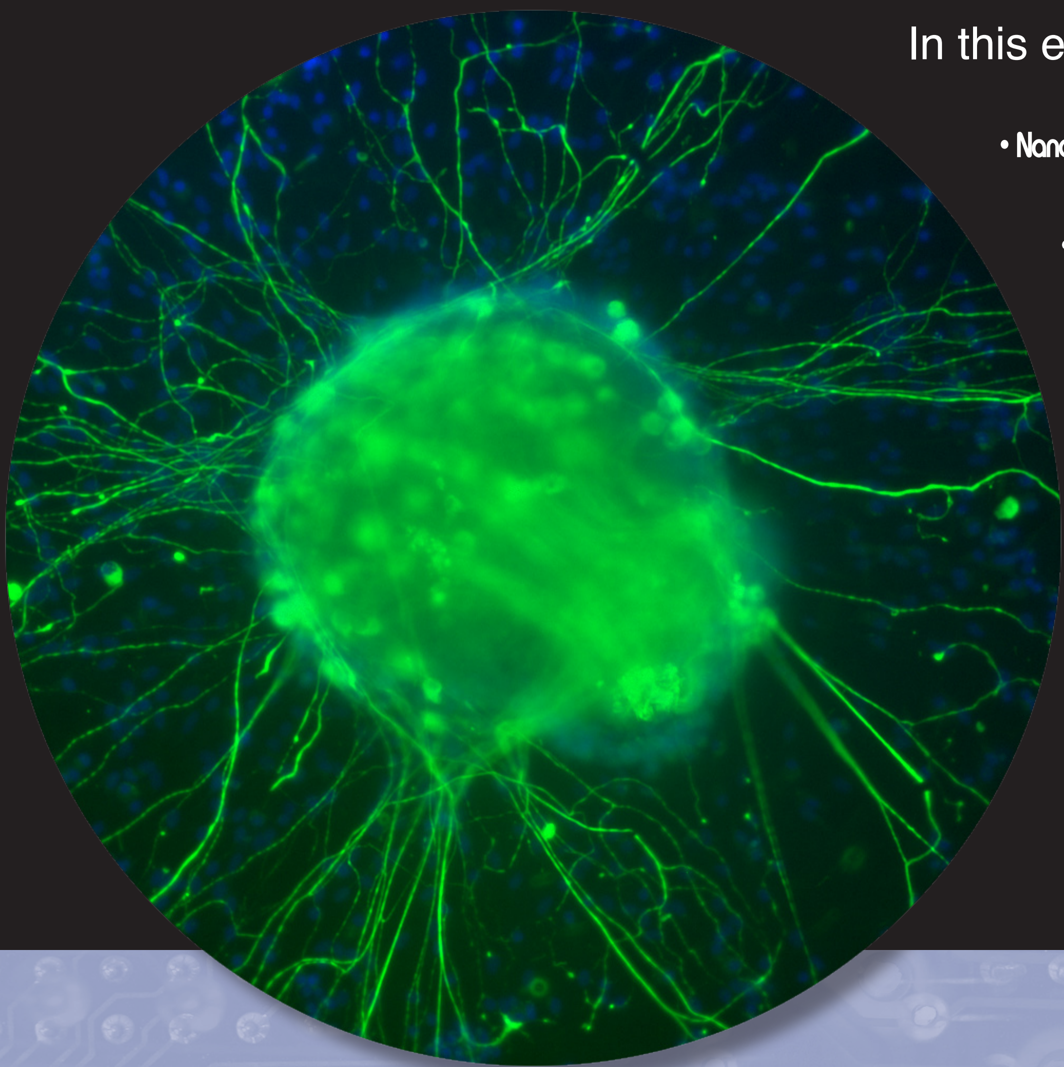
# NANO Q

BIG SCIENCE MEETS THE VERY SMALL



In this edition:




Issue 2

Australian Research Council
Nanotechnology Network

Australian Government
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# Welcome

## by Professor Chennupati Jagadish

### Convenor of Australian Research Council Nanotechnology Network

Welcome to the second 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 Research Council Nanotechnology Network's flagship conference, International Conference on Nanoscience and Nanotechnology (ICONN), will address various issues such as occupational health and safety, standards, regulation, ethics, social impact, environmental effects etc. ICONN 2010 is planning to feature these issues and if you are interested in getting involved with these activities, please contact Ms. Liz Micallef.

This issue features recent developments in nanobionics, nanotechnology for water treatment, nanoscale crystal engineering for photocatalysis and solar cell applications, an item on a visit by Young Nano ambassadors in remote areas and a news item on the Hope meeting in Japan. To enhance interactions among PhD students in Asia Pacific, the Japanese society for promotion of science organised a meeting of PhD Students from 11 countries. Highlight of this meeting is participation of young researchers and Nobel Laureates and high profile researches in working in the field of nanotechnology. This meeting gave an opportunity for PhD students to meet Nobel Laureates and interact with them. Final article is on winners of inaugural Eureka Prize for technologies Defence or National security. This work is based on tunable infrared microspectrometers based on MEMS technology which provides colour images to defence personnel in the field and which also has a broad range of applications in biomedical imaging, agriculture, environment.

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, ARC 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 second issue of NanoQ

# NANO NEWS

## March 2009

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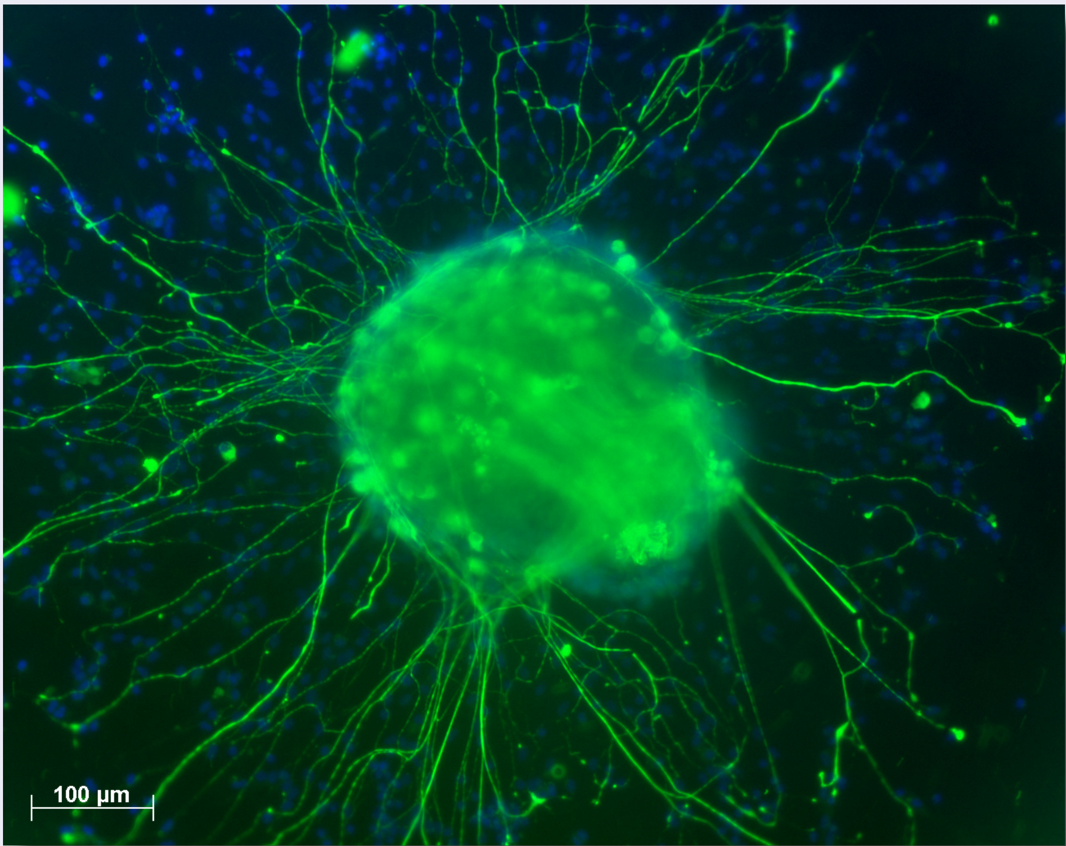
# Nanobionics

Simon Moulton, Geoffrey Spinks and Gordon Wallace
*ARC Centre of Excellence for Electromaterials Science, Intelligent Polymer Research Institute, University of Wollongong, Wollongong, NSW 2522, Australia.*

Bionic technology is making significant improvements in medical treatments and involves the efficient integration of biology and electronics. Advances in bionic technology result in improved quality of life, from the Cochlear Implant for the profoundly deaf to the replacement of limbs through the use of neural interfaced prosthetics. Efforts to improve currently available bionics through advancements in Nanotechnology have seen the emergence of the field of Nanobionics. As materials take on nanodimensions they take on extraordinary properties. An increased surface area means an increased interface with the outside world. The fact that the bulk interior is minimized is reflected in changes in electronic properties, and the removal of imperfections often found in larger structures drastically improves mechanical properties. On the biological front the nanotopography of surfaces has been shown to be critical. For example, Curtis et al [1] showed an increase in fibroblast response to materials exhibiting 13 nm nanotopographic features compared to planar surfaces. Of particular interest in the field of bionics is the effect of nanotechnology on electronic and mechanical properties of metals and organic conductors. Such materials provide an appropriate interface between biology and electronics.

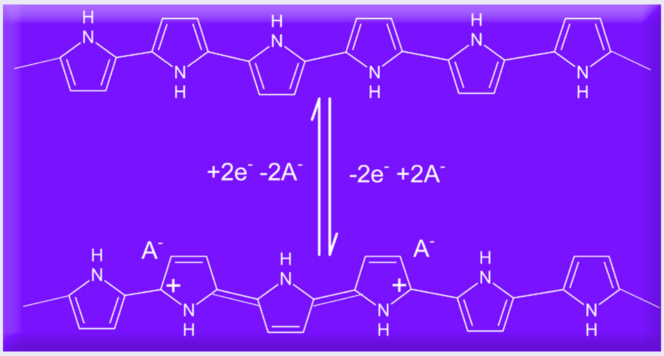
Critical to the biocompatibility of any bionic device is the way in which cells interact with the implant. Cell-substratum and cell-cell interactions play crucial




*Spiral ganglion neuron explant growing on a surface of polypyrrole doped with the nerve growth factor NT3 (Ppy.NT3) showing neurites growing out from the cell body.*

roles in biology and will therefore play a vital role in bionics development. The ability to manipulate these interactions through nanotechnology will facilitate improvements in the design of medical devices. Using nanotechnology to fabricate materials that elicit specific responses in living cells is proving to be beneficial. These new materials are increasingly being used in tissue engineering to accelerate cell reactions to implants by targeting specific gene expression.

The discovery of organic conducting polymers (OCPs) in the late 1970s revolutionised how we think about electronic conductors. Now at our disposal are electronic conductors that are organic in nature, and also a significant portion of the conducting polymer (the dopant) can be a biological entity. The soft character of OCPs coupled with their dynamic nature provides an extra dimension in designing interfaces between the hard, digital electronics world and the soft, amorphous world of biological systems. As a result, OCPs have emerged as having the potential to provide the basis of highly effective material platforms for Bionic devices. OCPs such as polypyrrole and polythiophene have the remarkable dual properties of conducting electricity and being able to be rapidly and reversibly switched between different oxidation states. This ability to electronically control a range of physical and chemical properties remains an area of intense and intriguing research activity. As we understand more of this behaviour we have turned our attention to a range of areas in which it can be utilised. Perhaps the most challenging of these areas is in bridging the Bionic Interface: providing a more effective conduit between electronics and biology.

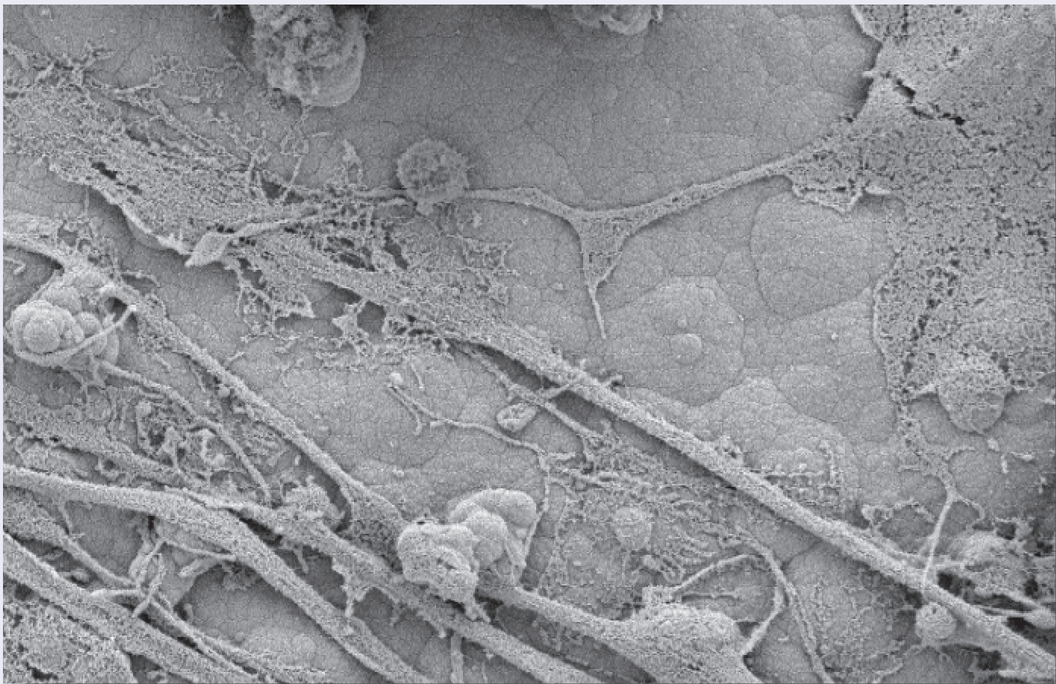



*Scheme 1. Oxidative and reduction scheme for polypyrrole. The A- represents the anionic molecule (dopant) incorporated during synthesis.*

The surface properties of OCPs at the nanoscale have been shown to influence cellular interactions. Surface functionalisation using small protein fragments such as laminin has shown to be effective in inducing desired OCP-cellular interaction. [2] To date, the use of the organic conducting polymer polypyrroles (Ppy – scheme 1) has attracted most attention. [3] For example, PC-12 [4] (nerve) cells can be cultured on Ppys - and cell differentiation can be stimulated via the electrically generated release of growth promoters which significantly increased the expression of neurites in the cells compared to the controls.

The use of biologically significant dopants has shown considerable improvements in neurite attachment and extension. Wallace et al [5] investigated the use of these novel platforms for culturing endothelial cells and explored the role played by fibronectin (an adhesion promoting protein). [6] More recently the nerve growth factor (NT3) has effectively been incorporated into and released from a Ppy polymer via electrical stimulation. [7] Significantly, this controlled release of NT3 was subsequently seen to have a positive effect on neurite outgrowth from Spiral Ganglion Neuron (SGN) explants (Figure 1). [8] When a protein polymer containing fibronectin fragments (SLPF) and a nonapeptide (CDPGY1GSR) were used as the PPy dopant, the cellular response was improved compared to CH3COO- doped PPy [9]. Glial cells appeared to attach better to PPy/SLPF-coated electrodes than to uncoated electrodes, while neuroblastoma cells grew preferentially on and around the PPy/CDPGY1GSR-coated sites. The PPy-CH3COO- coating on the same probe did not show a preferential attraction to the cells.

Much effort has been made to improve the properties of OCPs through the use of nanotechnology via the synthesis of nanoparticles, [10] nanofibers [11] or nanofilms. [12] As with metals, delving into the nanodomain has a dramatic effect on electronic properties, including improved conductivity and faster switching speed. [13] These attributes are yet to be fully utilised in medical bionic studies, however numerous laboratories are poised to exploit this. The advent of nanotechnology in the OCP world has also had a dramatic effect on processing capabilities and this is critical for creating appropriate bionic interfaces. The ability to provide stable nanodispersions means that inkjet printed tracks [14,15] can be produced; with micron resolution now achievable. The same dispersions are also amenable to wet spinning approaches [16,17] to provide long lengths of fibres again with micron resolution. As material scientists/engineers delve into the nanodomain particularly with OCPs – the boundaries between electronics and biology become fuzzy. This is exactly what we want – a seamless transition between the hard world of electronics and the soft world of biology!



*Scanning electron micrograph (SEM) of neurites growing on the surface of the Ppy.NT3 (images courtesy of Dr Rachael Richardson of the Bionic Ear Institute).*

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# Surface Engineered Silica for Water Treatment

Peter Majewski

*School of Advanced Manufacturing and Mechanical Engineering Mawson Institute*
*University of South Australia*

*Figure 1: Silica powder is the base for the Surface Engineered Silica.*

The United Nations World Water Assessment Program estimates that about 6000 people die every day from diarrhoeal diseases, caused by poor water quality and poor sanitation. 1.96 million people died in 2001, because they did not have access to clean water. The major part of these, 1.3 million, is under five years of age. The lives of more than one billion people are placed at risk because they do not have access to clean water. Organic pollutants such as bacteria and parasites in water are the main cause of water related diseases such as diarrhoea, worm infections, and infectious diseases. Consequently, the availability of drinking quality water is fast becoming an international major socio-economic issue. Current water purification methods are often complicated and requiring sophisticated equipment. They are also expensive to run, maintain and require skilled people to operate them.

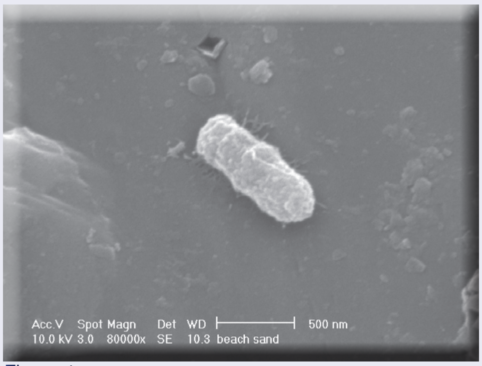



Figure 4:
Escherichia Coli bacterium sticking on SES particles

The research team of Peter Majewski has investigated how silica particles (Figure 1) can be easily coated with a nanometer-thin layer of active material based on a hydrocarbon with a silicon-containing anchor and a functional group which is interacting with the environment (Figure 2). The coating is formed through a chemical self-assembly process, and involves nothing more than mixing the ingredients to make the active particles without any organic solvents. The so called Self-Assembled Monolayer can be functionalised in order to provide strong negatively or positively charged surfaces of the silica particles. The charged surfaces can then electrostatically attract and immobilise charged contaminants, such as organic pollutants, which are generally negatively charged (Figure 3).

These active particles, Surface Engineered Silica (SES), have been tested to demonstrate that they could remove biological molecules, organic pesticides, detergents, and pathogens such as viruses like the Polio virus, bacteria like Escherichia Coli (Figure 4), and Cryptosporidium Parvum, a waterborne parasite. Cryptosporidium Parvum is a parasite that is ubiquitous in natural waters and extremely resistant to chlorination and various other water treatment methods. As a result it is responsible for serious gastrointestinal infections.

Current results show that organic species can efficiently be removed at pH ranges of drinking water by either stirring the coated particles in the contaminated water and filtering the powder or flushing the water through a filter which contains SES. The actual water treatment step does not require any additional energy or maintenance. Smaller particles sizes yielded better results as the observed effect strongly correlates with the available surface area of the powder.

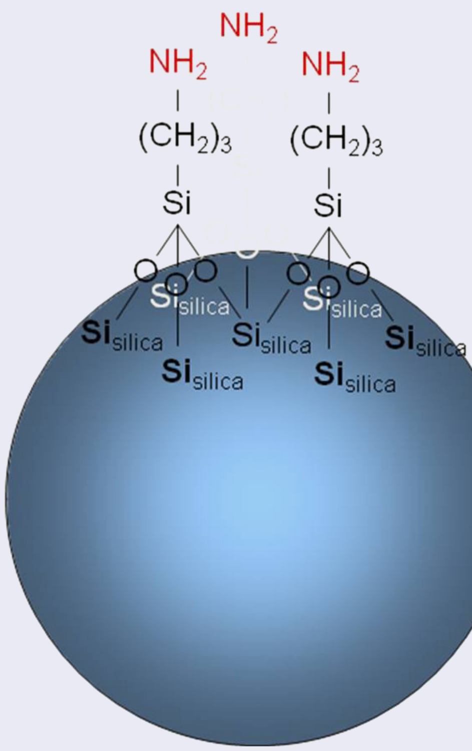



*Figure 2: Silica particle coated with a NH2 functionalised silane based surfactant.*

The developed water treatment method based on self-assembled monolayer technology provides a simple, versatile and easily scalable method that does not requires additional electric or thermal energy and may be operated in centralised and decentralised on-site and on-demand water treatment scenarios.

Current research activities focus the optimisation of the synthesis and processing of SES in order to increase its efficiency and the use of alternative silica sources, such as recycled glass. In addition, the cycling of used SES and the implementation of SES into exiting water treatment devices is an important research topic.

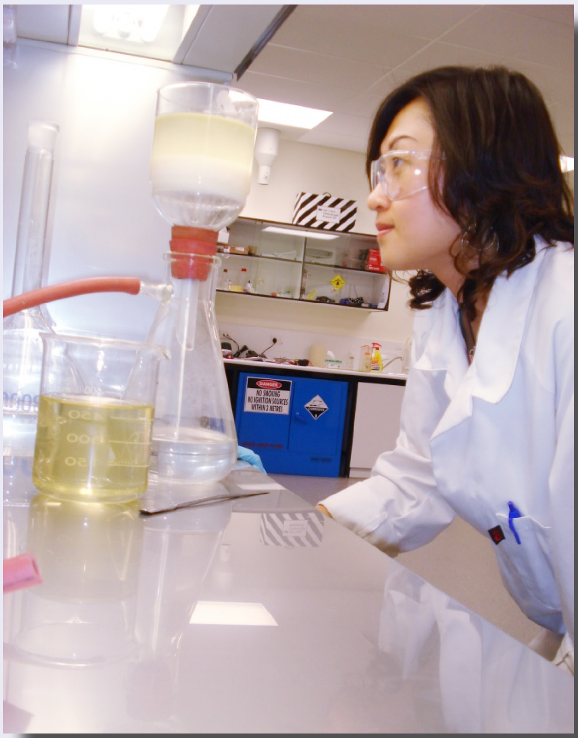
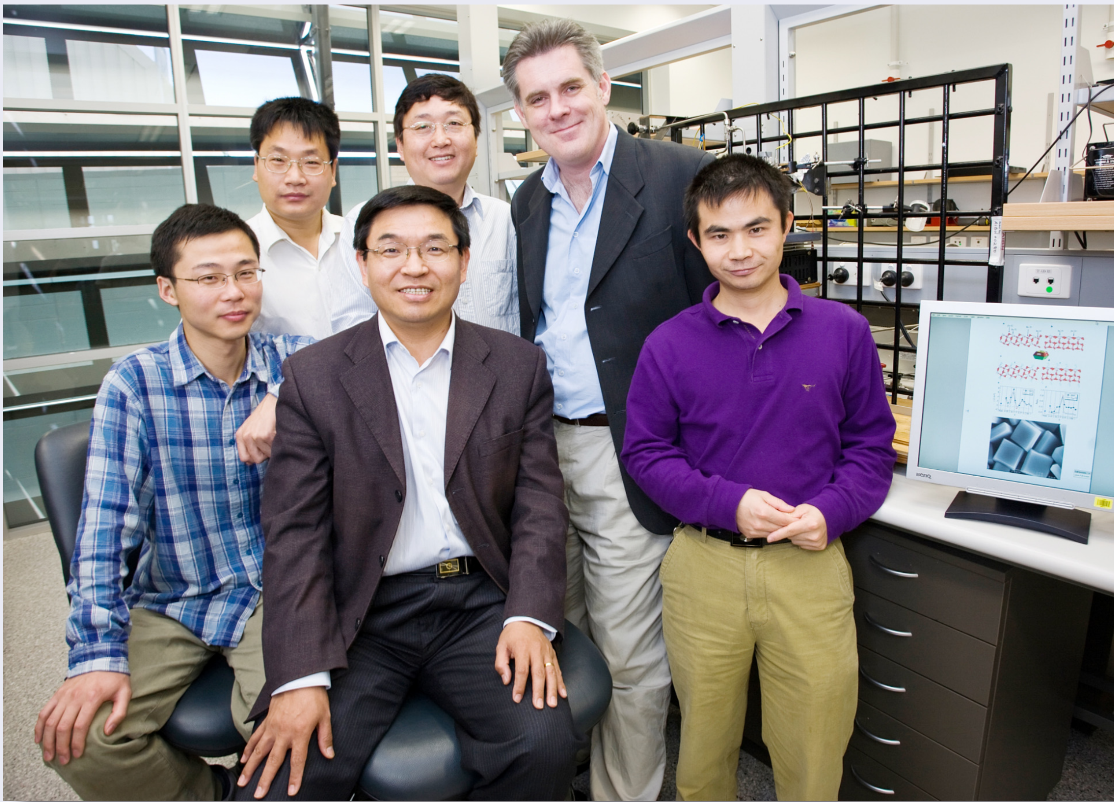


*Figure 3: PhD candidate Candace Chan performs a water treatment test using SES*

# Nanoscale Crystal Engineering

**In a world-first, researchers from the ARC Centre of Excellence for Functional Nanomaterials and The University**

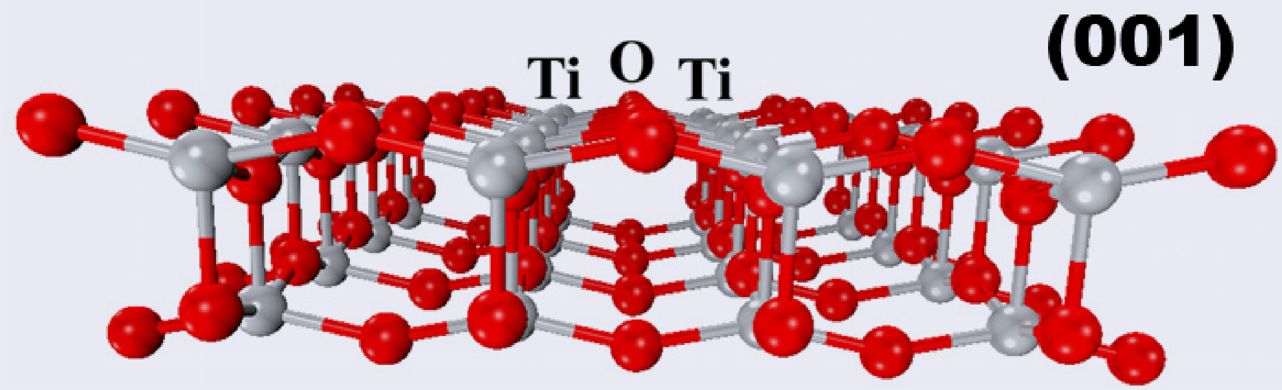


*Gang Liu, Huagui Sun, Max Lu, Shizhang Qiao, Sean Smith, Chenghua Sun (all from The University of Queensland).*

Photocatalysis is the acceleration of a chemical reaction in the presence of a photocatalyst. It is an important chemical process that underpins the development of critical environmental and renewable energy technologies such as photocatalytic water purification, hydrogen production from splitting water and high efficiency/low cost solar cells. The search for more efficient photocatalysts has intensified in the last decade because of the great significance of such photocatalysts in clean energy and environmental applications.

Owing to their scientific and technological importance as photocatalysts (among other applications), inorganic single crystals with highly reactive surfaces have long been studied. Unfortunately, surfaces with high reactivity usually diminish rapidly during the crystal growth process. A typical example is the photocatalyst titanium dioxide (anatase TiO2). Most available anatase TiO2 crystals are dominated by thermodynamically stable surfaces or facets (referred to as {101} surfaces in crystallography), rather that the much more reactive surfaces {001} – which account for only 3% of the total surface.

Researchers at The ARC Centre of Excellence for Functional Nanomaterials, in collaboration with the Chinese Academy of Sciences, have tackled this problem in a unique investigation which combines theoretical computational studies and experimental techniques to effectively manipulate the crystal-growth process to create a morphology with a high proportion of reactive sites. Initial computational studies indicated that among the 12 non-metallic

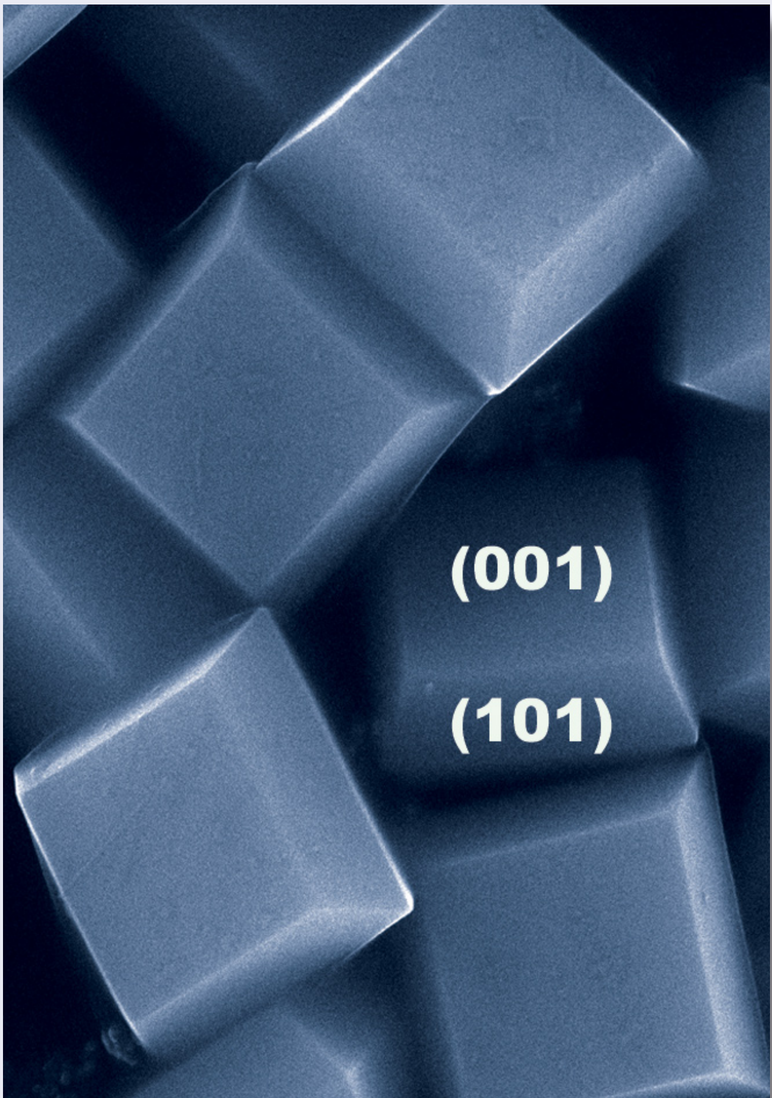



atoms investigated, controlling growth with fluorine (F) yields more stable atoms with a higher proportion of reactive surfaces.

Based on these theoretical predictions, the research group, led by Professor Max Lu, has successfully engineered the surface and crystallographic characteristics of crystalline materials to synthesise uniform anatase $TiO_2$ single crystals with a high percentage (47%) of reactive surfaces, using hydrofluoric acid as a morphology controlling agent. The fluorated surface of the single crystals can easily be cleaned using heat treatment to render a fluorine-free, high-purity anatase $TiO_2$ surface without altering the crystal morphology.

This work illustrates the power of combining theoretical computational studies and experimental techniques to achieve engineering of surface and crystallographic characteristics of crystalline materials and has been recently published in Nature (H G Yang et al, Nature, 2008, 453, 638 (DOI:10.1038/nature06964)

The well-defined, high-purity anatase single crystals synthesised in their work would be very useful as model crystals for fundamental studies of surface science. These crystals have promising applications in solar cells, photonic and optoelectronic devices, sensors and photocatalysis.




*Synthesised crystals of anatase $TiO_2$ with high proportion of {001} facets*

# The Innaugural HOPE Meeting

The inaugural HOPE Meeting for Nanotechnology was organized by the Japanese Society for the Promotion of Science (JSPS) as a means of fostering greater collaboration between early career scientific researchers in the Asia-Pacific Region. PhD students from 11 countries were invited to attend the 4 day conference held in Tsukuba Convention Centre, Tsukuba, Japan from the 24th to 28th of February 2008.

The first 3 days of the conference consisted of a series of talks and workshops from distinguished international researchers, including 4 Nobel Laureates (Leo Esaki, Heinrich Rohrer, Alan Heeger and Robert Laughlin). The topics discussed ranged from technical presentations into recent research, trends and future prospects for nanotechnology and more general discussion on the philosophy and techniques required to conduct effective scientific research. Renowned artist, Ikuo Hirayama, was also invited to give a presentation on the multicultural origins of Japanese society and culture. As part of the conference, the students were organized into focus groups which then gave a short presentation on a topic of their choosing.

The final day of the conference included a visit to the Advanced Institute of Science and Technology's Materials research division, where students were given an overview of synthesis methods for a new class of materials, "organic nanotubes", which are predicted to find application as a low-toxicity vehicle for targeted drug delivery. The visit also included a brief introduction to the single-walled carbon nanotube synthesis laboratory, where researchers are developing an automated high-efficiency method for producing low-cost high-purity carbon nanotubes. Participants were also given a tour of the NEC corporations R&D headquarters, where researcher Jaw-Shen Tsai presented an overview into the design and construction of the prototype microwave-addressable quantum computing device.

Following the laboratory tours, all participants were provided with a travel pass for Tokyo and the remaining day was spent visiting cultural and shopping sites throughout the city, with a farewell dinner overlooking the city.

# Young Nanotechnology Ambassador Award: Northern Territory Outback Science Tour

Joel Gilmore, Jenny Riesz and Andrew Stephenson

As recipients of Young Nanotechnology Ambassador Awards in 2007, we travelled to schools in the Northern Territory, presenting shows and workshops to students at both primary and high school level. We presented a brand new workshop focusing on nanoscience and engaged students with hands on experiments and investigations that lead into discussions about cutting edge technology. In total, we visited 2400 students in 14 schools over three weeks, engaging with some of the remote students in Australia.

## Background: The UQ Physics Demo Troupe

The Physics Demo Troupe was founded in 2002 by two then undergraduate students from the School of Physical Sciences, Joel Gilmore and Jennifer Riesz. It is a group of mainly undergraduate student performers who travel Queensland and beyond doing science shows, talks and workshops for schools and the general public on a volunteer basis. A key focus is reaching students in rural areas, who miss out on the outreach opportunities available to students living near Universities. Travelling as far west as Mt Isa and as far north as the Torres Strait Islands within Queensland, we have reached dozens of rural schools and several thousand students, and look forward to working with many more.

## Northern Territory Tour

As Young Nanotechnology Ambassadors for 2007, we decided to take on the ambitious venture of working with rural schools in the Northern Territory, travelling north from Alice Springs to Darwin over three weeks visiting very remote schools along the Stuart Highway, a total distance of nearly 2000km. These schools have a high proportion of indigenous students and rarely receive visitors, let alone from Universities. The awards from ARCNN and supporting grants from the University of Queensland, Australian Institute of Physics and Australian Academy of Technological Sciences and Engineering gave us a unique opportunity to engage with rural communities, to inspire students to consider careers in the physical sciences, and most importantly to train teachers, leaving resources to benefit students long after we're gone.

## Overview

Over three weeks, we visited 14 schools, 2400 students and clocked up over 3000 kilometres in our campervan. We had the opportunity to visit a range of schools, from well-funded private schools to small rural schools with very limited budgets.

The differences between schools were probably most apparent in our first week, based in Alice Springs. We worked with three different high schools: St Phillips, a private Christian school with about 1% indigenous students; Alice Springs High School a public school with roughly 20% indigenous students; and Yirara College a Christian run school for indigenous students.

St Phillips college was very academically inclined, rivalling many top schools in Brisbane. The teachers were very enthusiastic and the students had access to excellent facilities.

Students at Alice Springs High School, however, were not generally academically inclined. Teachers spend a large amount of time simply on discipline and crowd control, and several teachers told us that science curriculum was often cut to make time for basic literacy and numeracy. The science budget was equally limited. We found we had to inspire interest immediately or risk losing the students for the entire session.

Finally, we worked with students from Yirara College. Run and paid for by local Christian groups, the school provides education solely for indigenous students with a particular focus on students from very remote areas who may not have attended regular school beforehand.

Although the students are of Year 11/12 age, most are only at lower primary literacy level, making this the highest priority in the classroom. Again, we had to work hard to maintain interest over the two hour sessions, but the teacher commented "[I'm] amazed you kept them occupied and entertained for two hours!"

Another issue was that English was the second, or even third, language for many of the students, so we had to keep the language simple. Wherever possible we minimised talking and focussed on hands on experiments that could speak for themselves – the aim, of course, of almost all our workshops!

## Our Itinerary

**September 2007:**

| | |
|---|---|
| **Sat 8th** | Fly to Alice Springs, pick up campervan and supplies |
| **Sun 9th** | Purchase supplies, equipment, etc for shows |
| **Wed 12th** | Workshops at Alice Springs High School and shows for Gillen Primary School |
| **Thur 13th** | Workshops at St Philip's College |
| **Fri 14th** | Workshops at Yirara College and shows at Bradshaw Primary |
| **Sat 15th** | Preparation for journey (stocking of food and supplies) |
| **Mon 17th** | Shows at Braitling Primary School, driving to Ali Curung |
| **Tue 18th** | Shows and workshops at Ali Curung School, drive to Tennant Creek |
| **Wed 19th** | Shows and workshops at Tennant Creek State High School |
| **Thur 20th** | Shows and workshops at Tennant Creek Primary School, drive to Elliot |
| **Fri 21st** | Shows and workshops at Elliot State School |
| **Sat 22nd** | Drive to Katherine |
| **Sun 23rd** | Preparation for following week of shows and workshops |
| **Mon 24th** | Shows and workshops Katherine South Primary School |
| **Tue 25th** | Workshops for Katherine High School |
| **Wed 26th** | Continued shows and workshops for and Katherine High School, drive to Jabiru |
| **Thurs 27th** | Shows and workshops at Jabiru State School |
| **Fri 28th** | Continued shows and workshops at Jabiru State School |
| **Sat 29th** | Drive to Darwin, fly home |

The trip north towards Katherine was an eye opening experience, not only in terms of the vast distances in the Australian outback but also letting us experience the challenges that remote teachers face. The opportunity to visit and work with students in Ali Curung, an Aboriginal freehold settlement, was particularly rewarding.

The feedback we received from the teachers was overwhelming positive – particularly on the stretch between Alice Springs and Katherine, they were grateful that someone had taken the time and effort to visit their remote corner of Australia. We left our contact details and information on where to buy many of the equipment we used – we make a point of using cheap or DIY demonstrations wherever possible.

Below are outlines of the workshops we conducted, and we would be happy to provde detailed instructions, including scripts, for the demonstrations to anyone who is interested. We would like to thank the ARCNN for supporting us on this venture, and we look forward to many more such trips in the near future.

Sincerely,

Joel Gilmore, Jenny Riesz, Andrew Stephenson

## Nanomaterials workshop

How do materials really work? How does nanoscale structure change the properties of a material? From polymer slime to non-Newtonian fluids, students learn about what makes up materials on the nanoscale, and how we use this to make something useful. Sand that always stays dry, beads that change colour in the sun, and how Polaroid sunglasses work. Plus, a discussion of some of the latest technologies – including flexible screens and organic LCDs!

*Students from Yirara College investigate UV sensitive beads*

## The Physics of Air

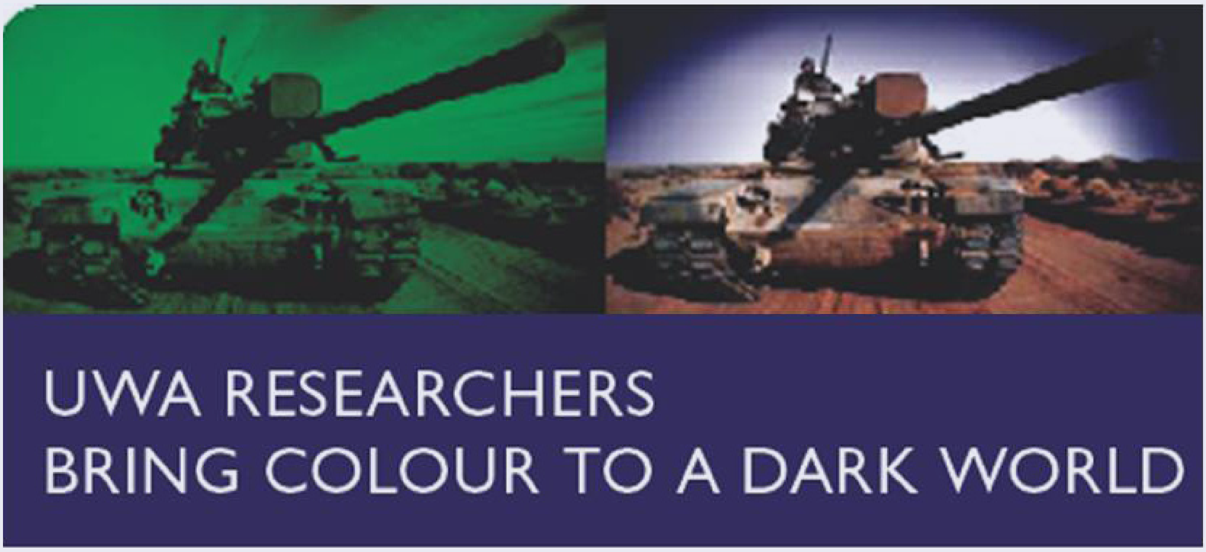
A 45 minute, highly interactive science show exploring air pressure, sound waves and energy. Is air pressure really strong enough to smash a ruler? How could a simple metal rod produce so much noise? And how can we use physics to launch a bouncy ball into the atmosphere? These are just some of the questions that students help us answer in an exciting show that they talk about for months!

*An "Airzooka" demonstrates that air can have a lot of power, particularly when it's spinning – just like a tornado!*

## Science "toys" workshop

An entertaining hands-on workshop where students study a variety of physics "toys" to discover what they do that's strange and then work out why they do it. Tops that flip upside down, water vortices and upside down fountains are just some of the experiments they'll explore. In the process students learn valuable problem solving skills, develop their analytical thinking ability, and learn about physics topics such as energy, angular momentum, conservation of energy and fluid dynamics.

*Investigating how whirlpools help to move water and air around reinforces concepts from the show, including the Airzooka*




# Colour TV to Save Aussie Soldiers

## Science in Support of Defence or National Security

WINNER - Microspectrometer Sensing Technology

Australian and allied soldiers' lives will be saved by new technology that brings colour vision to infrared sensing for the first time. The technology's creators, the Microelectronics Research Group of the University of Western Australia, were awarded the inaugural Defence Science and Technology Organisation Eureka Prize for Outstanding Science in Support of Defence or National Security for their microspectrometer sensing technology.

This prize is part of the Australian Museum Eureka Prizes, the Oscars of Australian science. Coveted among science prizes, the Australian Museum Eureka Prizes were announced at a glittering event in Sydney on 19 August attended by a 'who's who' of Australian science, government, academia and industry. The $10,000 prize was presented by the Minister for Defence Science and Personnel, Hon. Warren Snowdon MP.

Infrared 'night vision' technology is of major importance to many homeland and international defence systems. But existing infrared is unreliable and cumbersome, producing unclear black and white images (and not those green images so often seen in TV movies). The new system is the equivalent of a digital colour video-camera, but operating in the infrared part of the spectrum rather than the visible. Being 'hyperspectral', the spectrometer measures the energy at many separate infrared wavelengths, not just the equivalent of 'black and white'.

The Microelectronics Research Group, led by Professor Lorenzo Faraone, developed a filter which enables creation of colour images. The filter also allows scanning of smaller areas, meaning less data is required to generate images and improved real-time use of infrared. Impressively, the technology is lightweight, robust, compact, fast, accurate and inexpensive. The achieved miniaturisation essentially produced a 'spectrometer on a chip'.

Australian Museum Director, Frank Howarth, said "This new sensor will be a core component of future allied combat capabilities. It will revolutionise the use of infrared and lives will be saved as a result of this technology."


*The Hon Warren Snowdon MP (first from left) presents Professors Lorenzo Faraone (second from left) and John Dell (third from left) of the Microelectronics Research Group with their Australian Museum Eureka Prize.*

The new class of Aussie sensors will be used by ground forces and unmanned aerial vehicles. The improved technology will also assist soldiers operating in cluttered environments and urban areas, enabling them to scan for threats and targets from safer distances. Deaths from friendly fire will be reduced, as targets are better identified with colour images.

Significantly, the new infrared technology has wider applications in biomedical imaging, environmental monitoring, mining, viticulture and agriculture. Director of the Australian Museum, Frank Howarth, says "It is rare for one technology to be applicable to so many fields. It is also extraordinarily accessible, inexpensive and reliable."

It is envisaged that lightweight, hand-held detectors will be used in biopsy-free skin cancer testing, real-time soil monitoring and characterisation of grain during harvesting.

The Microelectronics Research Group is a world leader in the innovative combination of micro-electromechanical systems and infrared imaging technologies. Their work is protected by a number of international patents. And the Group is almost unique in obtaining a $3.5 million grant from the US Defence Science and Technology Organisation, which rarely awards funds overseas.

The $10,000 Defence Science and Technology Organisation Eureka Prize for Outstanding Science in Support of Defence or National Security is awarded to an Australian individual, group or organisation for outstanding science and/or technology that has developed or has the potential to develop innovative solutions for Australia's defence and/or national security. The University of Western Australia won the prize from a field of 11 high quality entries submitted by industry and research agencies across Australia.

*The lives of Australian and allied soldiers will be substantially safer thanks to revolutionary full-colour night vision technology developed by The University of Western Australia's Microelectronics Research Group. The new imaging technology has the potential to provide dramatically improved military applications, with threat and target recognition possible at longer distances with higher reliability. The technology has immense broader application that includes but is not limited to biomedical imaging, agriculture and food science. It is rare for one technology to be applicable to so many fields.*

Illustration based on an original image by Andrew Skudder

# Hairy electrodes for green cars

## How plasma technology promises to greatly reduce the cost of fuel cell manufacture

*Dr Christine Charles, Dr Cormac Corr, Cameron Samuell (Honours student), Wes Cox (PhD student) and Daniel Higginbottom (PhB student) with a hydrogen powered vehicle being developed to test the novel nanostructure fuel cells*

During the past few years there has been much talk in the media about hydrogen-powered vehicles providing a green alternative to petrol engines. Some cities such as Perth, have even introduced trial hydrogen busses on their regular routes. But one of the current obstacles to this green revolution is the high cost of hydrogen fuel cell power plants.

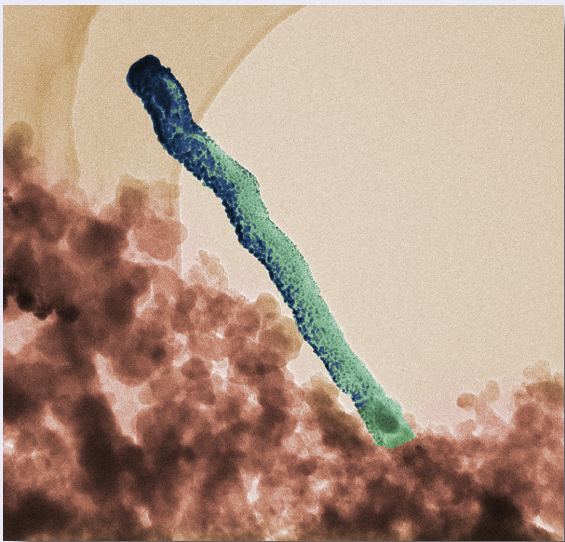
A fuel cell is a device for converting fuel, usually in the form of a gas, directly into electricity. There are many possible forms of fuel cell, but proton exchange membrane (PEM) cells are widely seen as the most promising option for road vehicles. In a typical transport PEM cell, hydrogen and oxygen gas are fed to catalytic electrodes at opposite sides of a special membrane that is porous to protons but not electrons. The proton and electrons are separated by the action of a platinum catalyst in the electrodes. The protons can diffuse directly through the membrane but the electrons have to make their way through an external circuit to reach the other side, providing power for an electric motor in the process.

Current PEMs typically employ a membrane of Nafion, a sulfonated tetrafluorethylene copolymer developed by DuPont. The problem with both Nafion and platinum catalysts is that they're both very expensive to produce.

Professor Rod Boswell and the Space Plasma, Power & Propulsion Group at ANU have been working with plasmas for many years and recently became interested in the possibility using plasma deposition technology to dramatically reduce the cost of making fuel cells. "Production of current cells frequently relies on wet chemical stages which are messy, inefficient and consume large amounts of expensive materials. Our aim is to develop plasma based techniques to create both the membranes and the catalytic electrodes needed in fuel cells." Professor Boswell says.

The group has had a number of recent successes in production of both membranes and catalytic electrodes.

The manufacture of electrodes begins with a substrate of carbon paper; chosen because it's both porous to the gaseous fuels used in the final cells and is also an excellent conductor of electricity. This is loaded into the plasma reactor chamber and a very fine layer of nickel is deposited on the surface. Under the right conditions the nickel forms nanoscale droplets all over the carbon surface. The next stage is to introduce methane and hydrogen into the plasma chamber. Many complex reactions ensue leading to a very surprising situation where carbon complexes diffuse through the nickel seeds to form multi-carbon complexes below. The highly reactive hydrogen protons in the chamber etch away any carbon atoms that aren't strongly bonded to each other. The practical upshot of this is that carbon nano fibres grow below the nickel droplets lifting them from the substrate as they extend. The result is a carpet-like covering of carbon nanofibres on the paper.



*False colour transmission electron micrograph of platinum deposits on carbon nanostructures. The platinum is blue in this illustration.*

Once the forest of nanofibres has been created the next step is to sputter coat the surface with platinum. "During the sputtering process the nanofibre tips get thickly coated with platinum with the droplets becoming progressively sparser further down the fibre. It's very much like snow falling in a forest, a lot gets deposited on the tree tops which greatly reduces the amount on the ground." Professor Boswell explains.

The tremendous advantage of this nanotechnology electrode is that its vast surface area and microscopically thin platinum coat reduce the amount of platinum required to about 15% of that in a conventional electrode of the same power specification.

The group has also succeeded in creating proton membranes by plasma decomposition of Trifluoromethanesulfonic (triflic) acid on a silicon wafer substrate. The finished membrane being detached from the wafer at the end of the process so it can be used for the next growth.

To make the finished fuel cell, the membrane is sandwiched between the hairy sides of two of the carbon catalytic electrode sheets and the whole assembly is hot pressed into a single sheet.

The new fuel cell technology is exciting stuff and may well be a key part of the transition to clean transport. But professor Boswell warns, "It has to be a holistic approach to clean transport. If you buy a cylinder of hydrogen today, chances are it was made from fossil fuels – it would be better to just burn the fossil fuel directly. What we need are fuel cell vehicles running on hydrogen that is inturn generated by clean electricity from solar or hydro. Then we'd be getting ahead."

At the moment it costs about six times as much to run on hydrogen as petrol. However, with petrol costs continuing to climb and the possibility of economies of scale in hydrogen production and distribution, it may not be all that long before that economic balance shifts.

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