

NANO

BIG SCIENCE MEETS THE VERY SMALL

In this edition:

• Scott Butcher - Turning on the Lights

• Golden Seeds to Grow
Nanowire Lasers

• Young Nanotechnology
Ambassadors Take
Nanoscience to School
Classrooms

• Measuring the Nano-Risks

Issue 1



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 first 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 2008 will be held in Melbourne during Feb 24-29, 2008.

This issue features recent developments in solid state lighting, nanowires for next generation electronics and photonics, measuring nanorisks and a news item on visits of Young Nanotechnology Ambassadors to schools to educate school children about the recent developments in this field. Exciting school children about science is important for the future of science, engineering and technology and Young Ambassadors have been visiting many schools in urban and rural areas.

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 first issue of NanoQ

NANO

NEWS

February 2008

CONTENTS

SCOTT BUTCHER -TURNING ON THE LIGHTS2-3

GOLDEN SEEDS TO GROW NANOWIRE LASERS....4-5

YOUNG NANOTECHNOLOGY AMBASSADORS

TAKE NANOSCIENCE TO SCHOOL CLASSROOMS..6-7

MEASURING THE NANO-RISKS8-9

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Scott Butcher - Turning on the lights

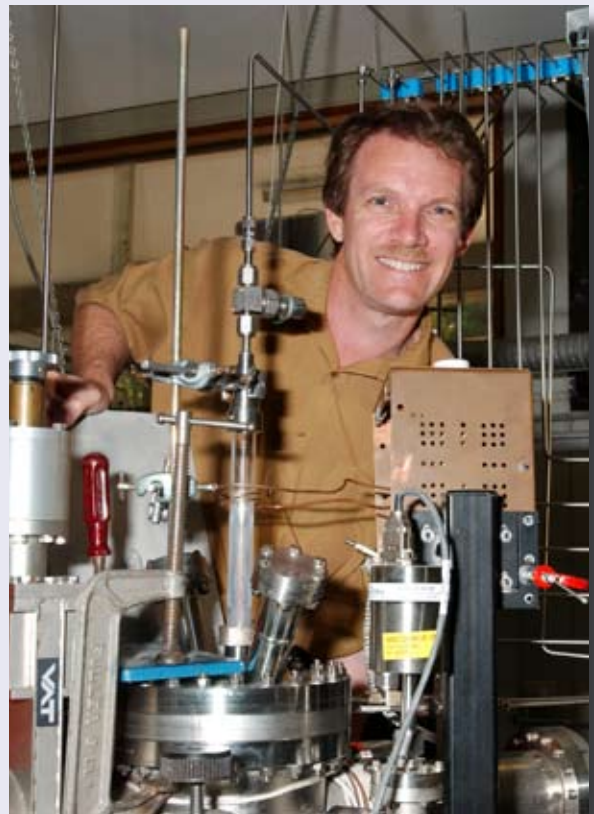
Gallium nitride and its uses

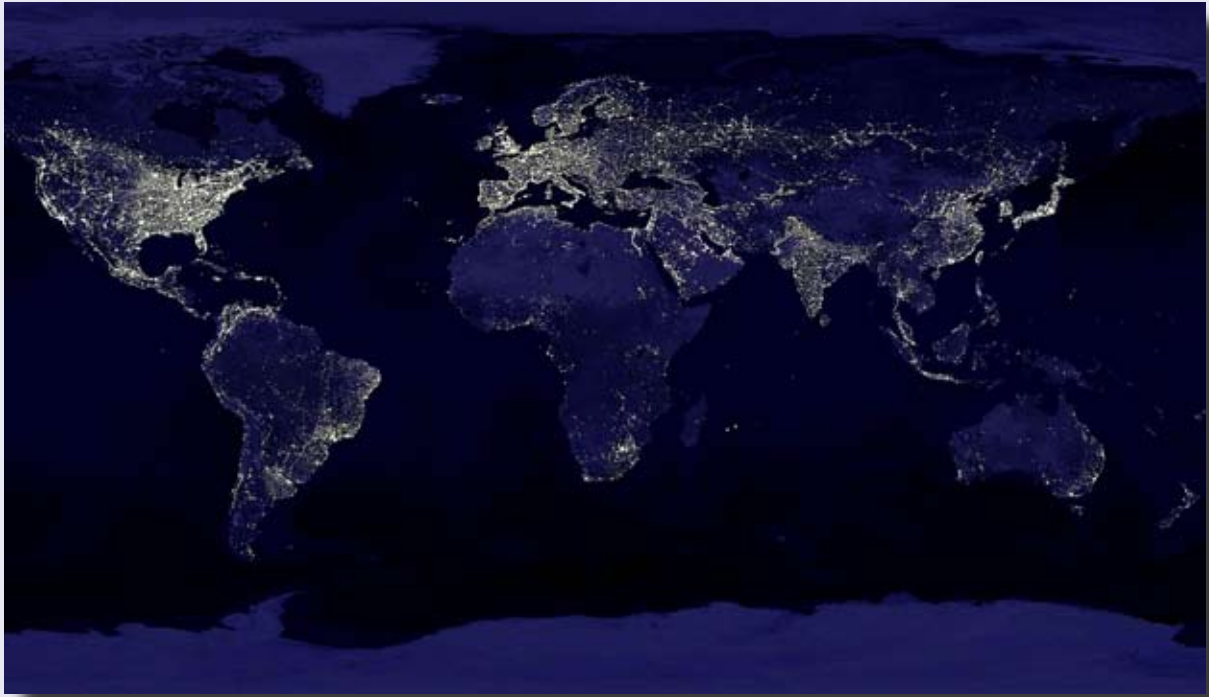
Devices using gallium nitride emit visible light when an electrical current is passed through them. High brightness blue and white gallium nitride LEDs are already used in a range of electrical devices familiar to most people such as scoreboards, digital clocks, traffic lights, DVD players and mobile phones. In 2004 the worldwide market for these devices was US\$3.2 billion. However, current production of gallium nitride is very expensive because of the high temperatures of around 1000 degrees celsius that are required along with the use of synthetic sapphires on which the gallium nitride film is grown.

Lower temperatures will mean lower costs

BluGlass' chief scientist Dr Scott Butcher, who was also an Australian Research Council Research Fellow in Macquarie's Department of Physics, has been able to grow gallium nitride using different techniques at much lower temperatures of around 650 degrees Celsius. It has enabled him to use glass rather than synthetic sapphires in the growth process thus significantly lowering the cost of production.

Butcher says the AusIndustry grant will allow for a much larger demonstration project of the world's first blue LED using glass. While the growth time will remain the same, Butcher says it will be possible to grow larger LED devices – a first step in the eventual transfer of the process into an industrial-scale system.





A world full of lights - at 57 Watts per light bulb, the energy saving moving to LED lighting would be staggering

Saying goodbye to the light bulb

The impact of the widespread replacement of current technologies with LED technology would be easily recognisable to most people in something as commonplace as the everyday light bulb. The light bulb as we know it today will have disappeared within the next 20 years, according to Butcher.

"A 60 watt light bulb would be replaced by a 3-watt LED, so there would be a big power savings, Butcher says.

Unlimited market potential

The switch already has the attention of multinational lighting companies such as Phillips and General Electric as well as major manufacturers of electronic components, according to Butcher.

"The market for such next generation technology is enormous – not only because of its wide number of uses, but also because of the potential to cut greenhouse emissions. It is currently a \$5 billion market and growing exponentially," he says.

Story by Greg Welsh

Helping researchers to be innovative

An on-campus scientific and engineering development facility is helping Macquarie's scientists stay at the cutting edge. The latest researcher to collaborate with Macquarie Engineering and Technical Services (METS) is Dr Scott Butcher, whose breakthrough in gallium nitride production led to the formation of a spin-off company – BluGlass Limited – last year. Butcher thanks METS for building a variety of essential prototype equipment, particularly a robust and reliable rotating stage for the heater.

Golden Seeds To Grow Nanowire Lasers

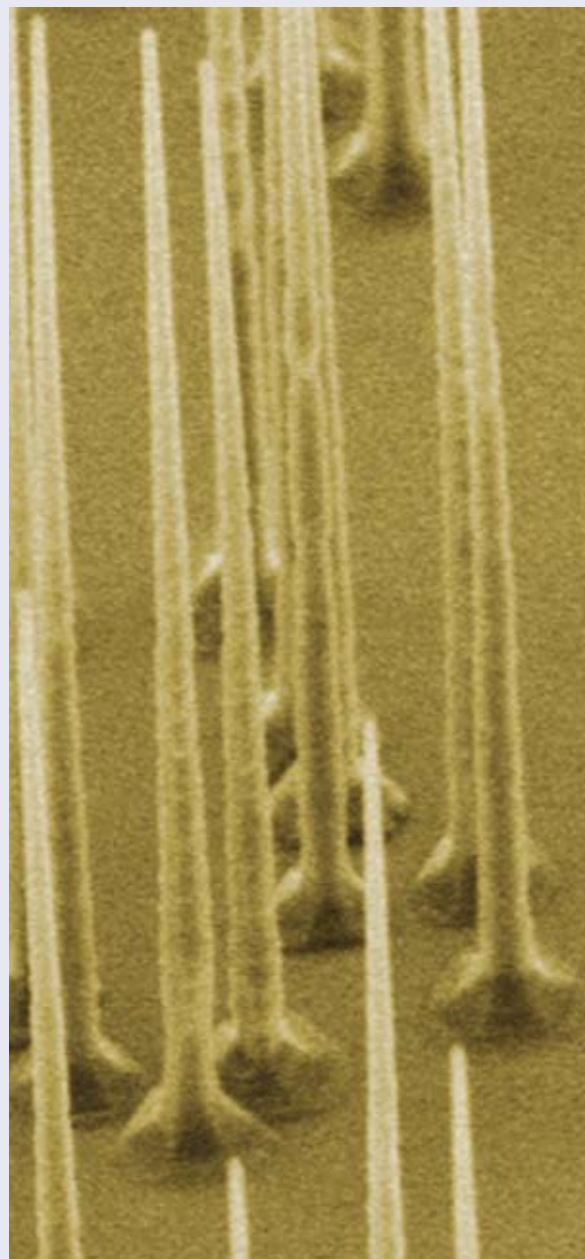
Under the right conditions, gold nanospheres on the surface of a gallium arsenide wafer can be induced to seed the growth of long nanowires.

Gallium arsenide is a semiconductor with many applications in solid-state lasers and detectors. One way to make such devices is a technique known as Metal Organic Vapour Phase Epitaxy or MOCVD. A complex molecule is formed between an organic group and the metallic component atoms of the required semiconductor. When passed over a heated substrate wafer, the molecules dissociate, depositing their metallic cargo atoms on the surface where they combine with arsenic from arsine dissociation to form new layers of semiconductor crystal. By changing the composition of the gases, it is possible to grow layers with different properties creating the sandwich structures needed for devices. The wafers can then be cleaved into individual device chips. The problem is that some devices such as nanowire lasers, can't be grown in a large sheet then cut into individual chips. They have to grow straight up like tiny hairs rising from the wafer surface. To create such devices, scientists at ANU make use of an interesting property of gold/ gallium arsenide mixtures.

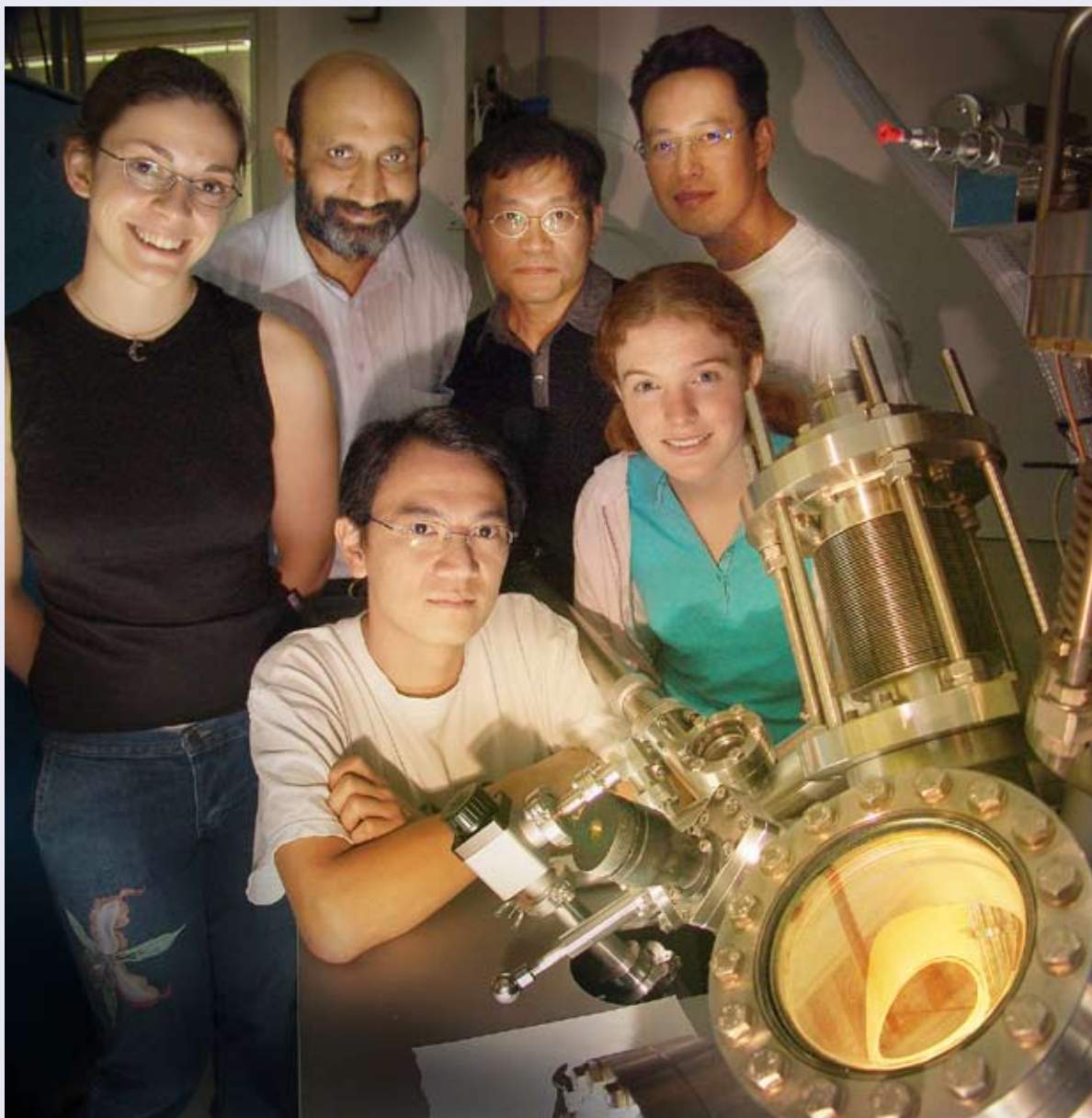
At the right temperature and pressure, gold and gallium arsenide form a eutectic - an alloy of the two materials with a lower melting point than either of its components. If a wafer of gallium arsenide is covered with microscopic gold spots and heated to just the right temperature, a tiny pool of liquid eutectic forms below each spot. When the MOCVD reactor is tuned to this eutectic point the temperature is too low for efficient deposition onto solid Gallium Arsenide so the metal organic and arsine

molecules deposit their semiconductor cargo on the wet eutectic below each gold seed rather than the wafer surface. This causes the material below the seed to grow and crystallise into miniature towers of perfect semiconductor pushing the gold seed and its eutectic base upwards as they do so.

Conventional fabrication techniques such as the



Nanowire lasers rise like skyscrapers from the substrate wafer. The base of these structures is only a couple of hundred atoms across.



Professor Jagadish and some members of his research team with a secondary ion mass spectrometer

masking and lithography used in computer chip manufacture, simply can't make gold spots small enough to seed good nanowires. So the ANU group use nanometer sized gold balls suspended in solution. Due to their inherent electrical charge, the tiny gold particles stick electrostatically to the surface of the specially prepared wafer in a similar way to toner on photocopy paper.

With the conditions set just right, these tiny seeds can grow perfect straight nanowires 50 times as long as their 200 atom thickness. The wires are then coated with another semiconductor, aluminium gallium arsenide, which has a lower refractive

index. This creates a tiny optical fibre only a few tens of atoms across. At one end of these fibres is the original gold seed, which not only makes a good laser cavity mirror but also a perfect electrical contact.

Due to their tiny size, such nanoscale fibre lasers can be modulated at vastly higher speeds than conventional telecommunications lasers offering the potential to speed up the networks. They also have very low threshold lasing currents reducing power consumption and unwanted heating effects.

Story by Tim Wetherell



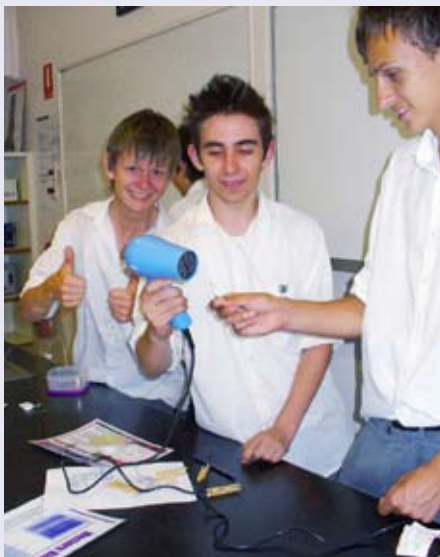
Young Nanotechnology Ambassadors take Nanoscience to School Classrooms

Since 2006 enthusiastic postgraduate and early-career researchers from the ARCNN have been visiting schools to inspire the future generation of scientists about nanotechnology as part of the Young Nanotechnology Ambassador Awards.

More than 1500 school students have so far experienced visits from the Young Nanotechnology Ambassadors. During these visits students have learnt about a wide range of nanotechnology topics, including an introduction to nanotechnology, electron microscopy, quantum dots, fuel cells and the application of nanotechnology in computers. Ambassadors have also discussed studying science at university and science careers in general.

The Young Nanotechnology Ambassadors have reported that one of the most popular elements of their school visits have been hands on scientific demonstrations. School students have participated

in activities such as the synthesis of gold nanoparticles, use of fibre optics and laser sizing, a hydrogen fuel cell device and the separation of ink colours using chromatography.



The Young Nanotechnology Ambassador Awards are valued at up to \$2000, including travel and presentation expenses, and two awards are made in each state and territory each year. Details on how to apply for the 2008 Young Ambassador Awards will be posted on the ARCNN website prior to the application deadline in June 2008.

Recent recipients of the Young Ambassador Awards include Satya Barik (ANU), Brianna Thompson (UOW), Jenny Halldorsson (UOW), David Piper (La Trobe), Ann Gooding (Melbourne), Carolina Novo (Melbourne), Kelly Bailey (CSIRO), Neerushana Jehanathan (UWA), Amanda Aloia (CSIRO), Katharina Porazik (UQ), Melvin Lim (UQ)

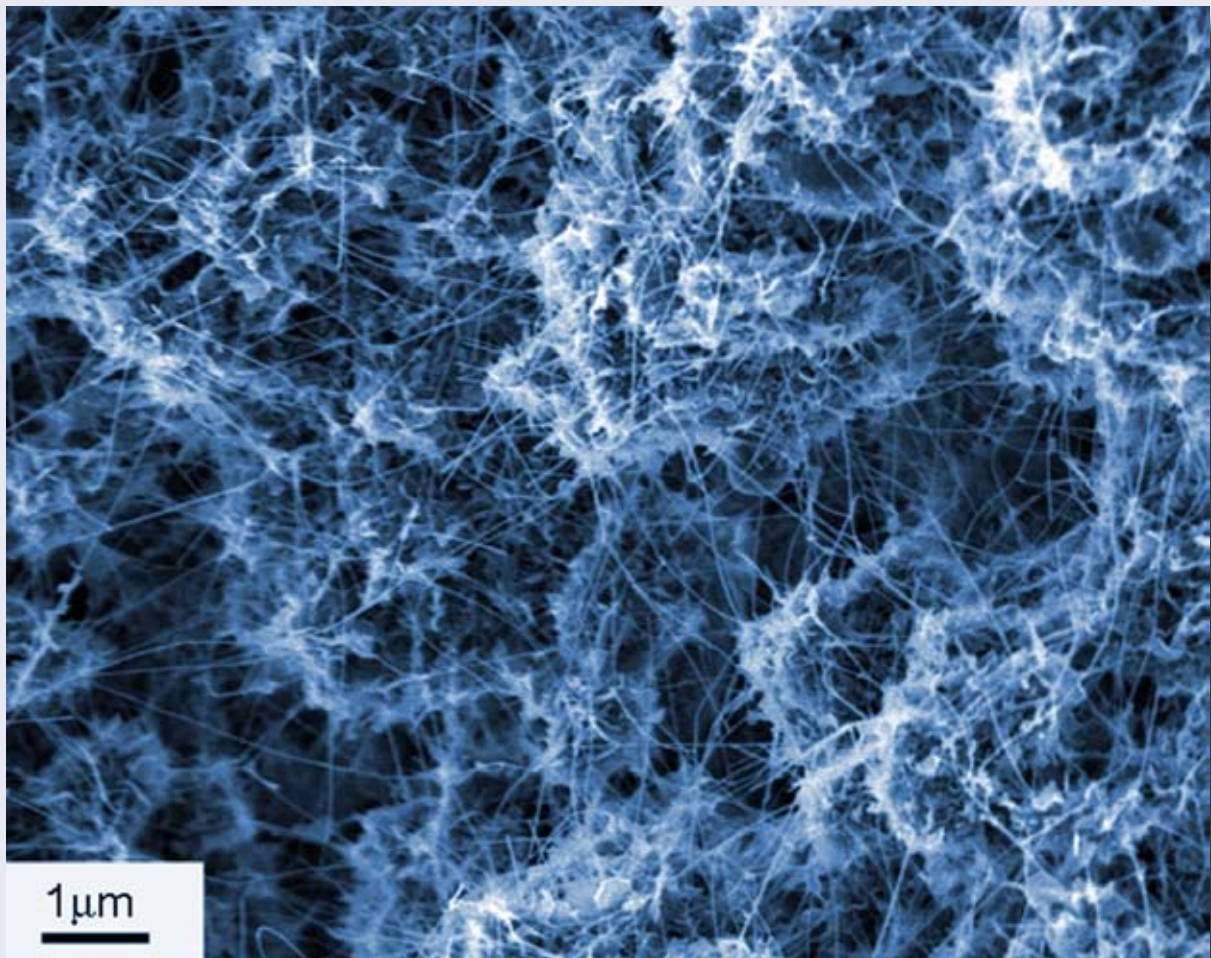
Measuring the nano-risks

Nanotechnology is a booming industry with the capacity to revolutionise our lives. But there are real concerns about the potentially serious health risks of nanoparticles, and the inability to measure these risks. However, in an article just published in the leading environmental science journal *Environmental Health Perspectives*, a team from Macquarie University has described a monitoring technique that could expose any possible health, environmental and social impacts of nanotechnology.

Nanotechnology is the engineering of materials on an extremely small scale. A nanometre is one-billionth of a metre, a human hair is 80,000 nanometres wide, and a nanoparticle is less than 100 nanometres wide.

Currently worth several billion dollars annually, by 2010 it is expected that nanotechnology will be a \$1 trillion industry. In Australia alone there are now more than 50 companies focused on nanotechnology, with the development of nanotechnology-based sunscreens, anticoagulant and drug delivery products well under way.

"Nanotechnology can potentially be used in many areas, including aerospace, agriculture, security, energy, information technology, medicine, transportation, consumer products and environmental improvement," explains Brian Gulson, Professorial Fellow from Macquarie's Graduate School of the Environment and head of the research team.



Nanoscale materials have the potential to revolutionise technology but materials of this size may also present particular hazards if they enter the body

Quick to jump on the nanotechnology bandwagon has been the cosmetics industry. Some of the biggest names in cosmetics are rapidly introducing nanomaterials into products such as cosmetics, soaps, shampoos, deodorants, sunscreens, toothpastes, nail polish and perfumes.

For many years zinc oxide and titanium dioxide have been the elements of choice for use in sunscreens because of their ability to filter UVA and UVB light but the disadvantage of these elements is that they are visible. However, used in nanoparticle form, zinc oxide and titanium dioxide can't be seen on the skin but still retain sun-screening properties.

According to the Australian Therapeutic Goods Administration, at the present time around 70 per cent of sunscreens with titanium dioxide and 30 per cent of sunscreens with zinc oxide have these materials in nanoparticle form.

So if researchers and manufacturers around the world are excitedly touting the benefits of nanotechnology, why should we be concerned?

Says Gulson: "Currently there is almost no research on the health impacts of nanoparticles despite the increasing use of such technology. There are also no occupational health and safety guidelines for production and use of nano products. There is therefore a potential risk to consumers who use products containing nanoparticles, to the workers who manufacture the products, and to the environmental systems in which waste nanoproducts are released."

Several reports from a number of leading academic groups including the UK Royal Society and the Royal Academy of Engineering, from the EU, the US National Science and Technology Council, and the Australian Government have expressed concern over the deficiency of knowledge of effects of nanoparticles on environmental, human and animal health and safety, both for consumers and workers.

The civil society group Friends of the Earth is even calling the commercialisation of nanoproducts one of the most dramatic failures of regulation since the introduction of asbestos due to the non-existence of safety testing.

Nanotechnology presents unique health risks because the physical and chemical properties of matter change when engineered at nano-scale. This means that the toxicity of nanoparticles cannot be predicted from the known properties of larger-sized particles of the same substance.

In addition, says Gulson, due to their small size there is the potential for adverse health effects arising from their ability to penetrate cell walls and the blood-brain barrier following inhalation, ingestion or via skin absorption.

Even more worrying, until now there has been no way of tracing the effects of nanoparticles on humans, animals and the environment because current methods of monitoring are ineffective due to the makeup of nanoparticles.

So, drawing on his background in geochemistry and toxicology, Gulson set about developing a technique that will be able to measure the exposure to nanoparticles in humans and the environment. His first project will monitor skin absorption of zinc and titanium in sunscreens and other personal care products.

Gulson will use the technique of stable isotopic tracing, whereby a stable isotope of the element of interest is incorporated into the product, allowing any transfer to be easily detected using mass spectrometry.

"By design, many nanotechnology products contain a metal," he explains. "In order to trace an element such as zinc, a stable non-radioactive isotope or tracer whose abundance is different from that occurring naturally is incorporated into the product. Because there is such a big difference in the

amounts between naturally occurring zinc and the tracer we will be able to track what's going on in people and the environment. We are in the process of conducting pilot investigations using ^{68}Zn [a zinc isotope] and later, ^{46}Ti [a titanium isotope], as tracers in sunscreen products containing zinc oxide and titanium dioxide to determine their dermal absorption and excretion in humans."

This pilot investigation, which has received funding via the Macquarie University External Collaborative Research Grants Scheme, is in collaboration with an Australian manufacturer of nanoparticles, Micronisers Pty Ltd and Nanovic.

The next stage will involve a more detailed investigation of skin absorption in lifesavers and a comparison with mice in collaboration with CSIRO and ANU. Funding for this phase is being sought from the US National Institute for Occupational Safety and Health.

Besides the isotopic aspects, says Gulson, these investigations will for the first time incorporate the highly sophisticated and sensitive gene expression arrays to evaluate potential free radical damage to DNA and also scanning electron and transmission electron microscope analyses to understand the fate of the nanoparticles in the body.

"Nanoparticle exposure in factory workers can be monitored from isotopic measurements of wipes from areas such as protective clothing, their hands and faces, or collection of biomarkers such as blood and urine," explains PhD student Herbert Wong, who is on Gulson's team. "Furthermore, simple surface wipes and/or dust accumulation methods could be used for air monitoring exposures, followed by isotopic analysis. We could also monitor the water that leaves the factory by looking at sewer and stormwater pipes and sediment."

Isotopic tracing also has enormous capability to measure other nanoparticles such as quantum dots. Quantum dots are crystals of semiconductor compound which are being researched for their potential use in targeting tumour cells and as drug delivery systems. Some contain highly toxic cadmium so are coated in zinc oxide to minimise exposure to patients. According to Gulson, there is currently considerable concern that the coating may degrade before the quantum dots are excreted from the body. The integrity of the coating, he says, could be monitored by using a single isotopic tracer such as zinc incorporated into the coating or incorporating a tracer of cadmium into the core material.

Story by Fiona Crawford



Nano-materials are finding their way into an increasing number of products, many of which come into close contact with the body



<http://www.ausnano.net>