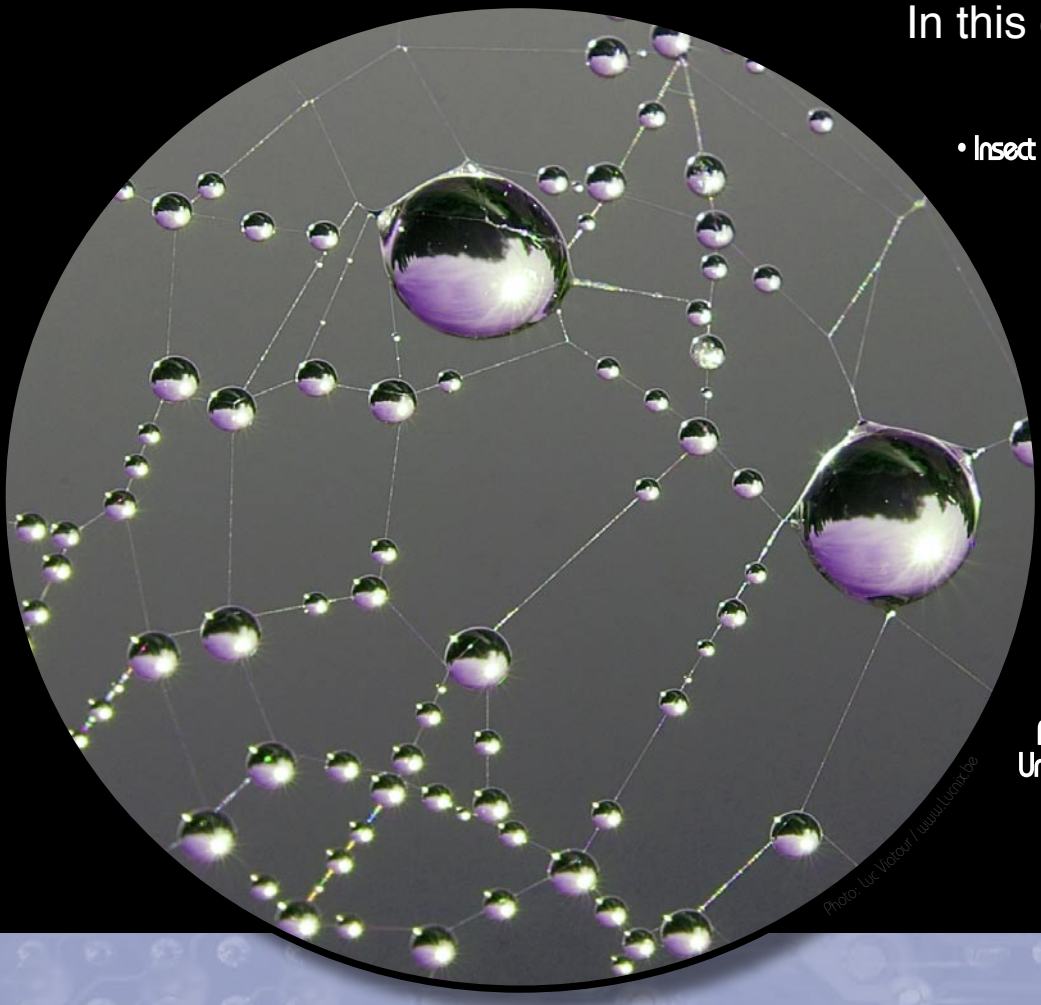
N·A·N·O·Q·

BIG SCIENCE MEETS THE VERY SMALL



In this edition:

Issue 5

Australian Nanotechnology Network

Australian Government
Department of Innovation Industry, Science and Research

Welcome

by Professor Chennupati Jagadish

Convenor of Australian Nanotechnology Network

Welcome to the fifth 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 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 2014 will be held in Adelaide during Feb 2-6, 2014.

This issue of NanoQ features insect silk and its properties and biomedical applications were discussed by colleagues from CSIRO. How layer-by-layer assembly process of preparing polymer capsules and their use in targeted drug delivery was discussed by colleagues from University of Melbourne. An innovative project carried out by University of Wollongong students interviewing CEOs of nanotech companies and their experiences and insights were discussed in "The Transition Project". How optical profiling techniques are enabling to measure nanostructure size and shape has been discussed by Macquarie University colleagues. Finally, Flinders University colleagues have discussed their work in bridging the gap between the university and industry research under the "NanoConnect" program.

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 Fifth issue of NanoQ

NANO NEWS

May 2013

Contents

To become a member of ANN contact:

Liz Micallef

Network Manager

Australian Nanotechnology Network (ANN)

Research School of Physical Sciences and Engineering

(Building 60)

The Australian National University

Canberra ACT 0200

Australia

61 2 6125 5952

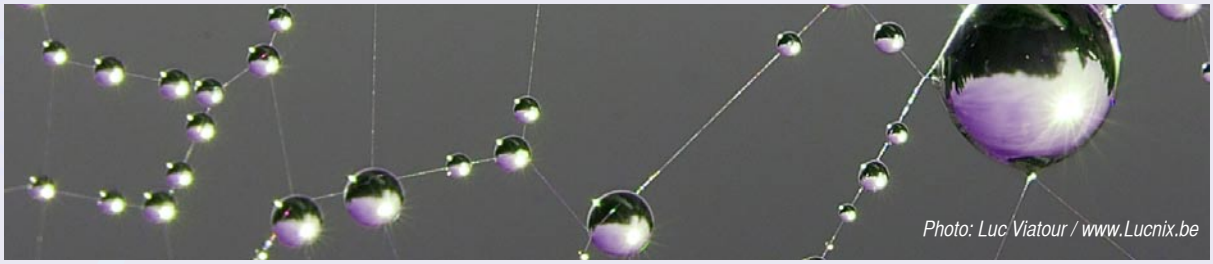
Liz.Micallef@anu.edu.au

www.ausnano.net

Australian Nanotechnology Network

Australian Government

Department of Innovation Industry, Science and Research



Insect silk spins a new story

Nancy Mills
Senior Communications Officer, Australian Synchrotron

At various times in its long and colourful history, silk has been more precious than gold, worn only by royalty, and used as currency. It has also been the subject of industrial espionage attempts by several countries despite the threat of death for anyone who dared to share China's secret.

CSIRO researcher Andy Walker and his colleagues are on a modern-day quest to uncover the secrets of silk production. But their target is not the silkworm, or even the spider. Instead they're pursuing honeybees, crickets, lacewings, webspinners, glow-worms, weevils, silverfish, dance-flies, praying mantises and others in the 23 insect groups that have independently evolved the ability to produce silk, along with mites, centipedes and crustaceans.

Over the centuries, silk has been admired for its smooth texture, elegant drape, beautiful sheen and strength for weaving and cloth-making. It has also been applied to more prosaic purposes such as wound dressings and fishnets. More recent uses include cross-hairs in telescopic sights and diffraction gratings, and research is underway into medical applications such as 'microneedles' for drug delivery, stem cell growth matrices, and scaffolds for tissue regeneration and bone repair.

Silkworm silk consists mainly of a structural protein called fibroin. The other main component is sericin, a water-soluble, gelatinous protein that surrounds and holds in place the two central fibroin filaments in each silk fibre. The secret of the fibre's strength lies in its secondary structure, the way the protein chains line up in rows to create a regular, crystalline, more-or-less two-dimensional array called a 'pleated beta sheet'. Weak hydrogen bonds hold the beta sheets roughly parallel and the sheets are joined at alternating edges by less-ordered and more-flexible parts of the protein chain.

Silk properties of interest for modern biomedical applications include strength, stability, biocompatibility, biodegradability and optical properties. Artificial silk could be tailor-made for specific applications, and have other molecules embedded in it for additional functionality such as enzymatic activity. Some silk fibres can serve as scaffolds for peripheral nerve regrowth because they are biocompatible, degrade naturally within the body over time, and provide a structure along which the nerve can travel through the body. These fibres can be made bioactive by embedding them with neural growth factors to increase growth rate and control more accurately the direction of nerve growth.

Research groups around the world have tried to manufacture artificial silk with varying levels of success, using standard protein production systems. In theory, it should be possible to take a gene encoding a silk protein from an arthropod, insert it into bacteria, and use the bacteria to make silk proteins very cheaply and at high volume. The

Photo: Lacewings hatching by Tim Wetherell

bacterial silk proteins could be then made into artificial silk using processes similar to those used to make nylon and Kevlar fibres from synthetic polymers. Unfortunately, silkworm and spider silk proteins are very long and very repetitive proteins, which makes it very difficult to get bacteria or any other type of cell to produce them.

However, silks made by species other than silkworms and spiders have different molecular structures. Reasoning that these might be better for artificial production, Andy and his colleagues are investigating silk proteins and structures across the arthropod lineages.

While arthropod silks vary in structure, all silk fibres are semicrystalline, i.e. they have regularly-structured crystalline regions (such as pleated beta sheets) as well as disordered regions. This combination of order and disorder gives the silk fibres the combination of strength and flexibility required to catch food, build shelters, protect eggs, and so on.

Because the crystalline regions are made up of protein structures that repeat across length scales of 0.1 to 5 nanometres, they act as tiny diffraction gratings and scatter light of suitable wavelength, such as x-rays. Small-angle x-ray scattering (SAXS) and wide-angle x-ray scattering (WAXS) detect this type of scattering at different angles, and provide information about structures that are repeated in silk fibres at long and short length scales respectively. SAXS and WAXS also tell us how the crystalline structures are aligned in silk fibres.

Using the Australian Synchrotron means Andy can routinely collect high-quality data from silk fibres over a few seconds where weaker x-ray sources might require exposure times of up to 50 hours.

Other methods used by Andy and his colleagues include infrared spectroscopy and Raman spectroscopy, which give information that is averaged for all the protein bonds in a silk fibre, and complement SAXS/WAXS data about the crystalline regions. They also use computer algorithms to predict what sort of structures the silk proteins will form based on nucleotide sequences in silk genes, and employ mechanical tests.

The researchers' synchrotron data demonstrate a bewildering variety of molecular structures in the silk fibres made by arthropods. In many cases, silk proteins and silk production show strong convergent evolution between species that have independently evolved the ability to make silk. For example, the group recently showed that silk made by some Australian crickets (family Gryllacrididae) is very similar to silkworm silk.

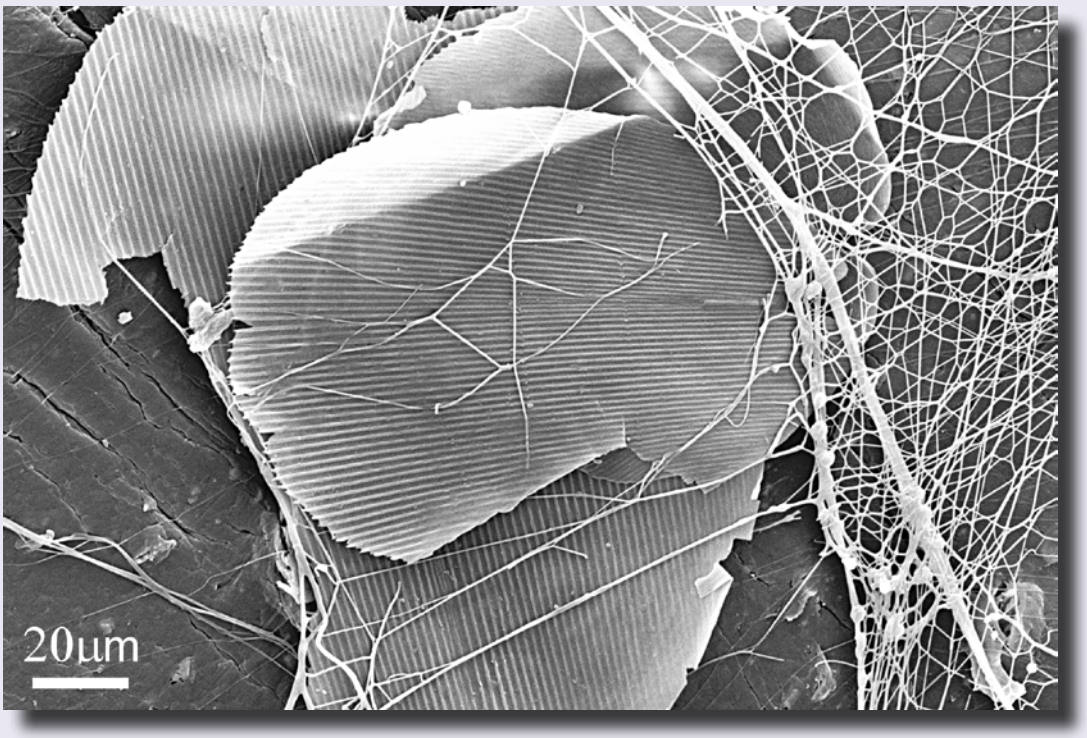
Green lacewing larval cocoon (Holly Trueman)

Synchrotron data have also shown that some species make silk with very different molecular structures. For example, honeybee silk and praying mantis silk are made up of proteins arranged in helices (coiled coil or alpha-helical molecular structure) rather than the extended strands and beta sheets found in silk from silkworms, spiders and crickets. Silk fibres made by some sawflies (the adult form of the 'spitfire' caterpillars found on gum trees) have the same structure as collagens in human connective tissue. Silk fibres made by female lacewings have a molecular structure called a cross-beta sheet structure, which is rare in humans but present in the amyloid fibrils associated with Alzheimer's and other neurodegenerative diseases.

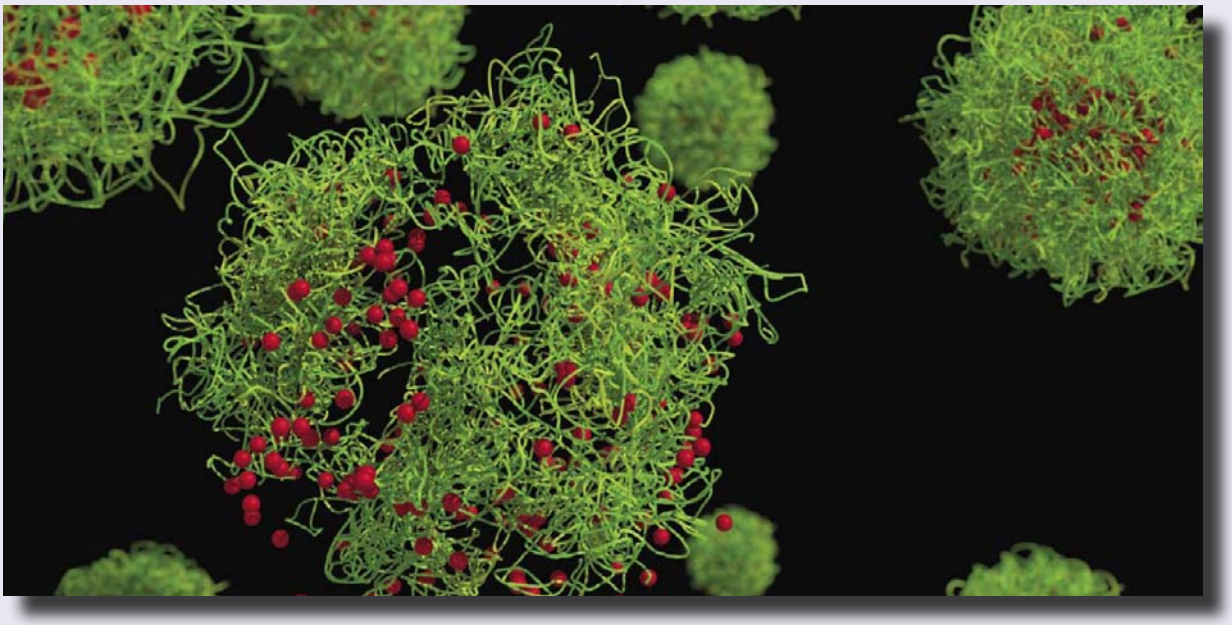
From the wealth of diversity present in natural insect silk proteins, Andy and his colleagues have identified some proteins that are much better suited to large-scale artificial production than silk proteins from silkworms and spiders.

Their next steps will involve further investigations of how silk proteins evolve—with the aim of demonstrating which features are most important for silk fabrication and discovering more of the detail of how silk fabrication actually works. Coupled with these investigations are ongoing experiments producing artificial silk. The process of making artificial silk involves a large number of variables, especially when such properties as immunogenicity and susceptibility to proteolytic cleavage are taken into account.

The research group's ultimate aim is to develop processes for making artificial silk with appropriate nano-level structures that mean the fibres can be used for tissue engineering, drug delivery, stem cell growth, biomonitoring, catalytic materials and super-textiles.



Broken scales and silk webs left behind after two silverfish mate (Andrew Walker, scanning electron microscopy, 515x)



Schematic illustration of polymer nanocapsules (green) loaded with anticancer drugs (red). Reproduced from Ref 1 with permission of The Royal Society of Chemistry.

Tiny Capsules Have Big Potential

by Mr Kang Liang

Department of Chemical and Biomolecular Engineering, The University of Melbourne

The design of nano- or micron-sized transporters for carrying anticancer drugs to tumour sites has emerged to be at the forefront for advanced therapeutic delivery in biomedical applications. Utilising polymer-based materials has played an important role in the development of such systems, largely because of the ability to prepare polymers with tailored properties, including biocompatibility, size, structure, and functionality. Several polymer-based vehicles have been reported, including polymer particles, polymer-based micelles, polymer-drug conjugates, and polymer nanocapsules. These systems can facilitate higher payloads, prolong the circulation time and solubility of the drugs, active targeting, and provide controlled-release of the therapeutics into the bloodstream or the targeted tumour tissue. Among these vehicles, polymer capsules are particularly attractive candidates for drug delivery applications.

Schematic illustration of polymer nanocapsules (green) loaded with anticancer drugs (red). Reproduced from Ref 1 with permission of The Royal Society of Chemistry.

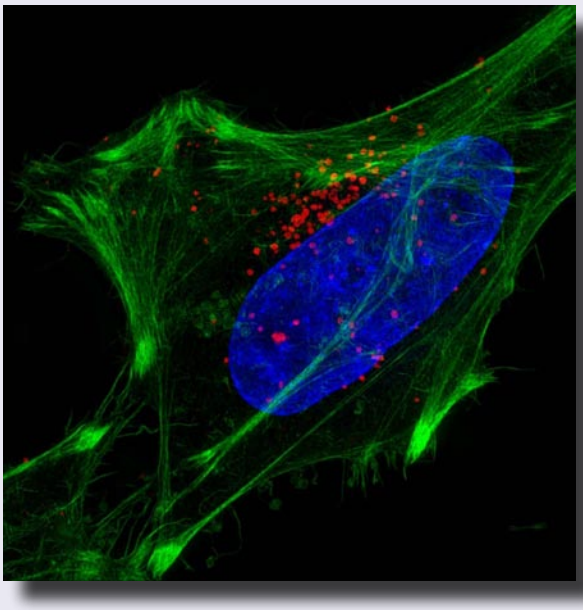
Layer-by-Layer (LbL) assembly processes have been widely used to prepare polymer capsules with well-defined chemical and structural properties. In LbL assembly, a sacrificial colloidal template is generally used to consecutively deposit multiple polymer layers one after another, followed by removal of the template, forming well-defined polymer capsules. These carriers can be

engineered to release their cargo at tumour-specific sites, based on the presence of physiological stimuli, such as pH, enzymes and redox-potential. In one such system reported by Nanostructured Interfaces and Materials Science (NIMS) group led by Prof. Frank Caruso at The University of Melbourne, it was demonstrated how several

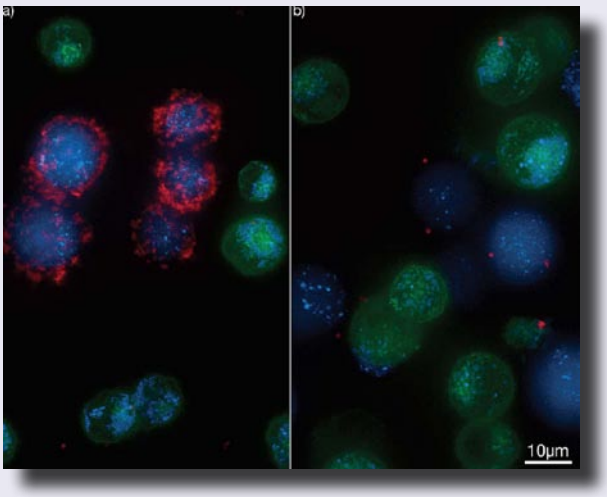
independent release mechanisms can be brought together and synergistically function to tune the cargo release profile. A novel class of polymeric nano- and micro-capsules with dual-responsive release mechanisms was generated via the versatile LbL technique and click chemistry. These capsules showed reversible size changes in response to artificial endocytic conditions, while retaining good colloidal stability. It was demonstrated that these capsules could release cargo specifically in pH conditions that mimic intracellular acidic compartments. Further, the synergistic effects of pH and redox-potential allowed for rapid and efficient cargo release.[2]

Cellular uptake of polymeric capsules (red). The blue stain shows the cell nucleus.

Recently, other exciting work from the NIMS group reported that polymer drug carriers could be engineered to selectively target cancer cells in a mixture with non-targeted cells. This was achieved by targeting an antigen that is specifically expressed on the surface of colorectal cancer cells. An antibody that is specific to this antigen, humanized A33 monoclonal antibody (huA33 mAb), was conjugated on the surface of polymer capsules via click chemistry. These huA33 mAb modified



Cellular uptake of polymeric capsules (red). The blue stain shows the cell nucleus.

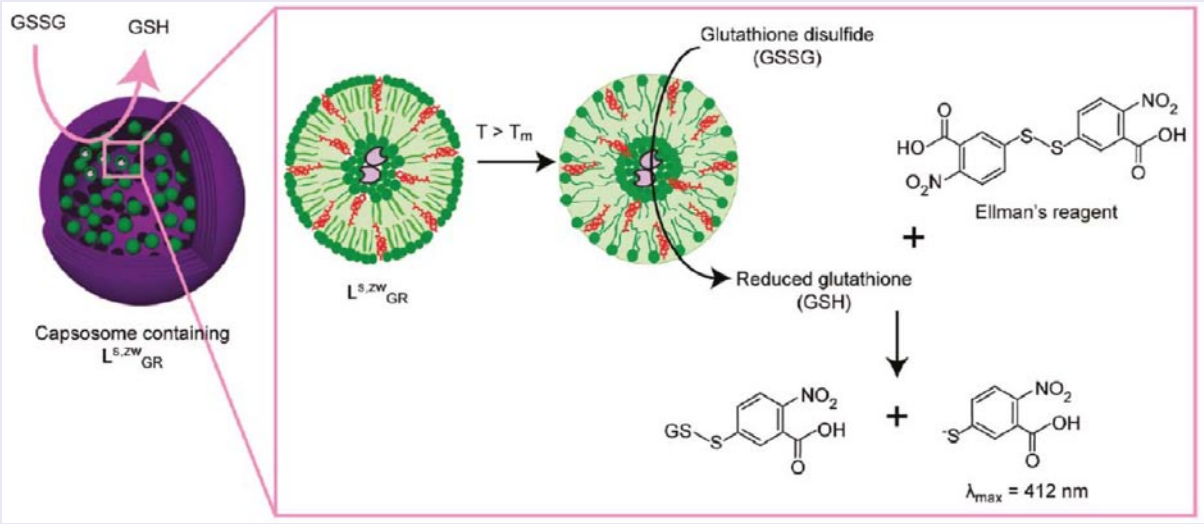


Fluorescence microscopy images of colorectal cancer cells (blue) and healthy cells (green) incubated with (a) huA33 mAb- or (b) IgG-functionalized capsules (red). Reprinted with permission. Copyright (2010) American Chemical Society.

capsules only bound to colorectal cancer cells when compared to a control functionality (IgG); even when cancer cells constituted less than 0.1% of the total cell population.[3]

Fluorescence microscopy images of colorectal cancer cells (blue) and healthy cells (green) incubated with (a) huA33 mAb- or (b) IgG-functionalized capsules (red). Reprinted with permission. Copyright (2010) American Chemical Society.

Beside drug delivery, polymer capsules have also been exploited for their potential in replenishing missing or deficient cellular activity. One of the important features of biological cells is their capability of performing of multistep biochemical reactions in a confined, subcompartmentalised environment. One strategy to create subcompartmentalised capsules is through the incorporation of liposomes in the polymer capsules to form 'capsosomes'. Free liposomes were built into polymer capsules via the LbL approach between liposomes and interacting polymers on a colloidal sacrificial template. When the template is dissolved, thousands of liposomes are bound inside the polymer capsule.



Temperature-triggered catalysis of encapsulated GR in the liposomal subcompartments of capsosomes, which reduces GSSG to its sulfhydryl form GSH. Reprinted with permission. Copyright (2011) American Chemical

In this study, the glutathione reductase (GR) enzyme was encapsulated in the liposomes, and then these liposomes were used to synthesise capsosomes. Glutathione (GSH) is an important cellular antioxidant that prevents damage to cell components caused by free radicals. This sulfhydryl reducing agent

predominantly exists at a concentration of approximately 5 mM in cells due to the activity of GR, an enzyme that actively reduces glutathione disulfide (GSSG) to its sulfhydryl form, GSH. The presence of this enzyme is essential for maintaining intracellular levels of GSH and to mitigate oxidation to avoid dysfunction of biologically active molecules. The GR-loaded capsosomes demonstrated excellent enzymatic activity by reducing GSSG to GSH by a built-in temperature trigger, showing their potential for treating diseases on the cellular and subcellular levels.[4] Several studies have shown that a decrease in GR activity is age related and a low GSH/GSSG ratio results in an increased level of oxidative stress and suboptimal immune responses.

Temperature-triggered catalysis of encapsulated GR in the liposomal subcompartments of capsosomes, which reduces GSSG to its sulfhydryl form GSH. Reprinted with permission. Copyright (2011) American Chemical Society.

In summary, small polymer capsules have demonstrated their big potential in a broad spectrum of biomedical applications. Given the fast progress in materials science and nanotechnology, these capsules are expected to increasingly impact the biomedical field.

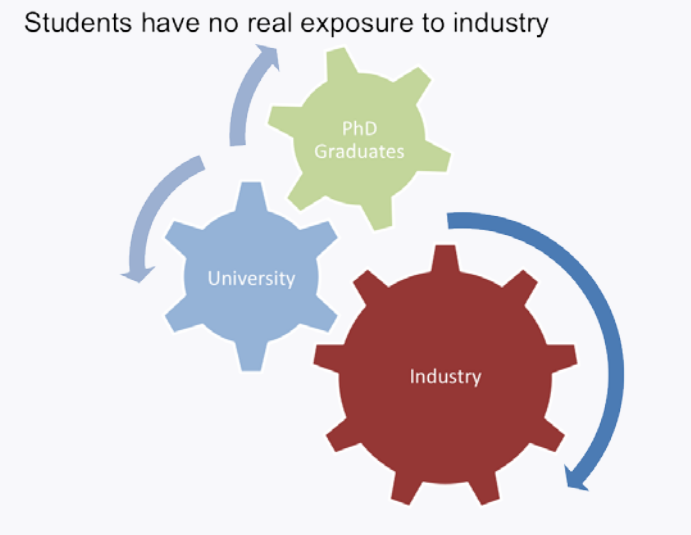
References: [1 Such, G. K.; Johnston, A. P. R.; Caruso, F. "Engineered Hydrogen-Bonded Polymer Multilayers: from Assembly to Biomedical Applications." Chem. Soc. Rev. 2011, 40, 19. [2] Liang, K.; Such, G. K.; Zhu, Z.; Yan, Y.; Lomas, H.; Caruso, F. "Charge-Shifting Click Capsules with Dual-Responsive Cargo Release Mechanisms." Adv. Mater. 2011, 23, H273. [3] Kamphuis, M. M. J.; Johnston, A. P. R.; Such, G. K.; Dam, H. H.; Evans, R. A.; Scott, A. M.; Nice, E. C.; Heath, J. K.; Caruso, F. "Targeting of Cancer Cells Using Click-Functionalized Polymer Capsules." J. Am. Chem. Soc. 2010, 132, 15881. [4] Chandrawati, R.; Odermatt, P. D.; Chong, S.-F.; Price, A. D.; Städler, B.; Caruso, F. "Triggered Cargo Release by Encapsulated Enzymatic Catalysis in Capsosomes." Nano Lett. 2011, 11, 4958.

The Transition Project

Mr Willo Grosse and Mr Dennis Antiohos

PhD candidates Australian Centre of Excellence for Electromaterials Science (ACEs)

University of Wollongong



Statistics show that 80% of PhD graduates work in the private sector once they finish their studies. However, academia seems to be in a parallel universe, where PhD programs are factories to turn out PhD's trained for an academic career.

Do you think that perhaps it's time we built a bridge between academia and the nanotech industry in Australia and developed a way to manage a smooth transition for scientific research and brilliant minds? ACEs thought so, we agreed , and that's why we jumped at the opportunity to be involved in The Transition Project.

What is the Transition Project?

The Transition Project is a way to engage industry through student dialogue. As students, we got the chance to interview CEO's in the Australian nanotech industry and ask them hard questions. We asked questions about their vision for their companies, their strategic goals, and what underpins their organisational culture?

Wait until you see what we found out!

But first, you may want to know how on earth three PhD candidates got to spend hours of quality time with innovative and entrepreneurial business leaders in our field of science? How did we get the chance to walk in, shake their hands and build rapport to the point of relaxed, intimate discussion and conversation on a first-name basis? The program is a novel way to establish trust relationships between students, their research institutes and industry, bringing these three cogs closer together to build the bridge. The Transition Project, and most importantly its inventor Chris Gilbey (ACEs Entrepreneur in Residence), facilitated the interviews through personal networks and an intense "Boot Camp" that helped build our interpersonal interview skills.

The Transition Project team from left; Research Manager Nicky Martin, PhD students Dennis Antiohos and Willo Grosse, and Director Chris Gilbey.

The Transition Project was designed to enhance the visibility of active nanotech research capabilities in Australia, gain an understanding of what industry needs in order to be globally competitive and improve profitability, and, significantly for us, to identify what additional skills PhD graduates need to develop in order to add to their core PhD research disciplines and how useful these skills are in the context of becoming relevant and valuable to industry.

The Boot Camp

It was important for us to learn the art of interviewing. We had to learn how to ask questions that warranted a discussion response instead of a yes/no answer that is guaranteed to abruptly stop a great conversation in it's tracks. Making a personal impression allowed the subject to feel comfortable to fully engage in the conversation and to offer their innermost thoughts on the topic. This provided an opportunity for us to dig even deeper, ask even more difficult questions and get to the nuts and bolts of what drives the need for research. The first phase of the boot camp also involved identifying the target companies. The three students involved workshopped a number of companies and undertook desktop research on them. We ultimately chose Cochlear, Ceramic Fuel Cells Ltd, and The Allen Consulting Group among others.

We worked with the COO of our facility to practice our interview skills. He gave great feedback and was very supportive and as a result, by the time we walked into the target company CEO's office, we were prepared for pretty much anything.

The Questions

Some of the key areas investigated in the interviews included: (i) efficiency of technology transfer into the community; (ii) whether government and university commercialisation policies benefit or hinder technology transfer; (iii) the effects of government policy; and (iv) how the skills of PhD students can be improved in order to aid employers and industry and themselves. We also asked them about what skills gaps they were experiencing in their current workforce and what they were looking for so we could understand how to position ourselves in the job market. They offered their opinion on what

has helped lead to their own and their companies' success, who their greatest competitors were and what they were doing to ensure their workforce is motivated to deliver on their company vision.

Industry Views

All of the interviews conducted had transcripts that were analysed for common trends. We identified five main industry views:

1. Business culture is important to understand. Working in an organisation is very different to the university environment and sometimes it is difficult to communicate between the two worlds. PhD students need to understand that their PhD does not provide practical experience for working in industry, and if they want to be able to apply their high level of technical knowledge in an industry setting, they need some experience.

2. Appreciate the power of government policy. The CEOs felt that grant schemes used by the Australian government do not facilitate effective technology transfer. Research institutes may be well connected with industry but they need to have a competitive publication output to secure their next round of funding. They are motivated by publications that lead to funding which means they have little real knowledge in patent strategy, and as a result they tend to not develop commercially viable IP. There is a perception that they waste valuable time and resources trying to commercialise IP that is not necessarily relevant, instead of investing more time into forging successful innovation relationships with Australian nanotech industry.

3. Changes need to be made at the university level. It was a common opinion that universities "do not deal sensibly with (intellectual property)" (Dyesol) or show "any real desire to work with industry in a practical way" (Cochlear). There is a perception that universities are so strict with their IP that it is difficult to find a win/win collaboration and generate profit and outcomes for each party.

4. Doing business with universities is not worth the investment. There is a strong perception that innovating through a university commercialisation unit is a waste of money because there is a very real possibility that they will receive nothing back from their investment. The CEO of Australian CleanTech, John O'Brien said, "They'll just wreck it."

5. The importance of personal networks. It's not what you know, it's who you know, and this is more important than ever in today's job market. When a company employs you, they are not just recruiting you personally but your whole network too. The CEO of Ceramic Fuel Cells said "SEEK is like a supermarket, whereas LinkedIn is like a boutique store". It was a clear message to us PhD students, to get out there and network.

Where Do We Go From Here?

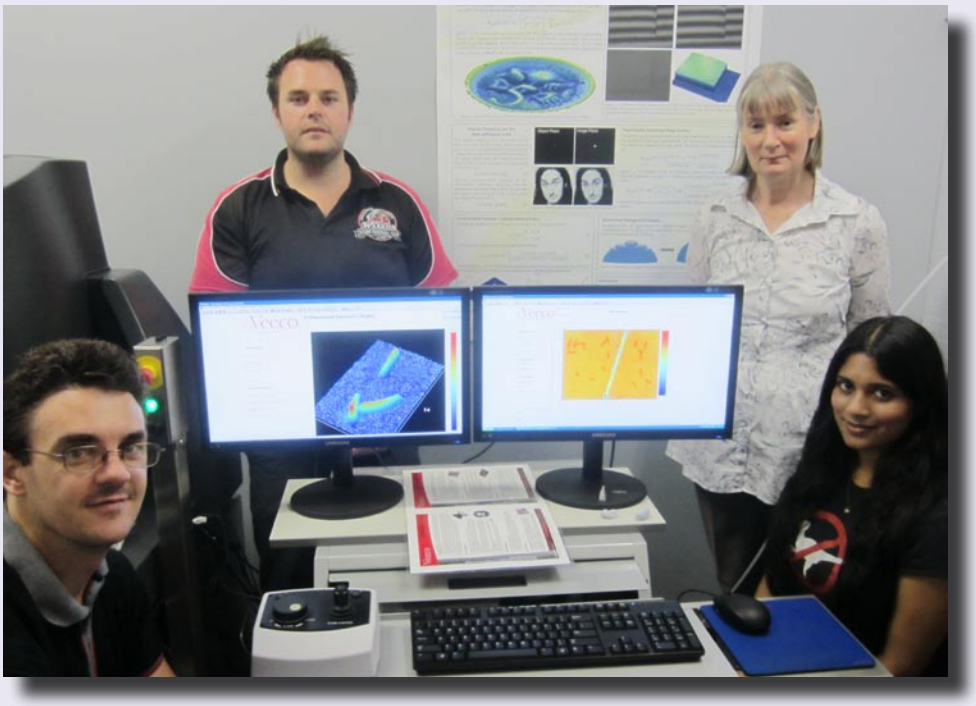
The Transition Project is going ahead with new students and new target companies in 2013 and we are excited about the outcomes. Having successfully engaged with industry, increased our visibility and that of our research institute and made a number of highly valuable personal contacts, we feel it was an incredible learning curve as PhD students. However, it doesn't take a rocket scientist, or a brain surgeon or a nanotechnologist to understand that a bridge cannot be built from one side. With enough momentum, a project of this kind has the potential to change the game for students, universities, government and Australian industry; and together, our global competitiveness in an increasingly flat world.

We would like to thank the Australian Research Council Centre of Excellence for Electromaterials Science for the opportunity, our other PhD candidate, Priyanka Jood, our research manager, Nicky Martin, our journalist student intern Tarant Hill and of course our mentor, Chris Gilbey, for their patience and hard work.

“VIEWS” for Studying the Nano-scale

Dr. Douglas Little, Mr. Adam Joyce, Prof. Deb Kane and Ms. Rajika Kuruwita

Research team at Macquarie University’s Optical Surface Profiler facility



The research team at Macquarie University’s Optical Surface Profiler facility. Clockwise from left: Dr. Douglas Little, Mr. Adam Joyce, Prof. Deb Kane and Ms. Rajika Kuruwita.

In 1879, Ernst Abbe discovered that the resolution of lens-based imaging systems was limited to around half the wavelength of light. This limit arises because of the way light diffracts (or spreads) as it propagates. This well-known paradigm limits the use of conventional optical imaging in studying the nano-scale, and so nano-characterization has traditionally remained within the domain of electron- and scanning-probe-microscopy.

There are plenty of reasons why we might want to use light to study the nano-scale. Photons are relatively benign compared to electrons and scanning-probe tips; and so it is easy to characterise objects without inadvertently modifying them. Light can also penetrate transparent materials, and so can potentially be used to measure objects in liquids, or underneath transparent layers. Finally, the physics that underpins how light interacts with matter is well understood, and so optical measurements are easy to interpret (It is considerably more difficult to interpret electron- and scanning-probe images as the physics underpinning these techniques is less well understood).

Studying nanoparticles however, does not necessarily require direct imaging. Often it is quantities such as nanoparticle size, nanoparticle shape or the separation between two nanoparticles that is of interest. It is theoretically possible that these types of quantities can be measured without constraints due to resolution limits.

A research team at Macquarie University is pioneering a new method to study the nano-scale, based on this concept. This method, called Visible Interferometric Electromagnetic Wave Scattering (VIEWS), is based on a form of microscopy called

interferometric microscopy and is theoretically capable of quantitatively studying nanoparticles down to 12 nm in diameter, using commercially available systems.

In standard microscopy, light is collected from a single focal plane (the object plane), which is then used to form an image. In interferometric microscopy, however light is collected from two focal planes (see fig. 1), one containing the object surface being studied and one containing a flat reference surface. Light from these two planes is then interfered, and the resultant interference pattern is digitally recorded.

Interferometric microscopes effectively behave as Michelson-Morley interferometers, except the phase of the object wave varies as a function of position over the object plane. Commercial interferometric microscopes called Optical Surface Profilers use this phase variation to calculate the height profile of an object surface. Fig. 2 shows a macroscopic surface profile of a five cent coin produced by stitching over a hundred microscopic surface profiles together.

Optical surface profilers are a standard, precision instrument for measuring surface roughness and profiling surfaces that are almost flat on the nanoscale. They have axial resolution as low as 0.01 nm (fig. 1). As such, they are already recognized as a tool for nanocharacterisation of flat surfaces.

So how can interferometric microscopes be used to measure the nano-scale in 3 dimensions? After all, interferometric microscopes are afflicted by the same lateral resolution limits as ordinary microscopes.

The answer lies in thinking in new ways about the distinction between lateral resolution and axial resolution. Lateral resolution can be thought of as the “in-plane” resolution; this is the resolution that is ordinarily referred to in microscopy and is limited by diffraction. The axial resolution is the “out-of-plane” resolution, i.e. the ability for the microscope

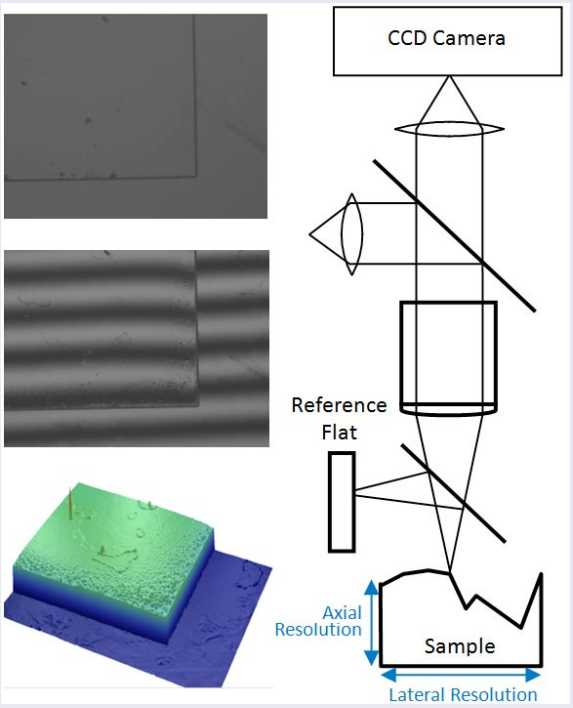


Figure 1 – Left: A standard microscope image of a step profile (top), the same image viewed under interferometric microscopy (middle) and the measured 3D height profile (bottom). Right: Basic configuration of an interferometric microscope. Blue arrows indicate the directions

to distinguish how distant an object is from the focal plane of the microscope.

The key is to leverage the excellent axial resolution obtained by optical interferometry.

The first clue to how this can be done came when making measurements of the height profile of gallium-arsenide nanowires fabricated by Dr Michael Gao and colleagues in the group of Professor Chenupatti Jagadish, at the Australian National University. Ms Rajika Kuruwita, working as an undergraduate vacation scholar with Professor Deb Kane, and with support by Mr Adam Joyce to use the instrument, found that the measured height profile was severely distorted. This was somewhat expected given that the nanowires were 50-100 nm in diameter, well below the (lateral) resolution limit.

However, it was clear that nanowires of different diameters could be systematically distinguished from one another. Even though the height

measurement was plagued by diffraction-based artifacts, the relationship between measured height and nanowire size seemed to follow a consistent, deterministic relationship. The group realised that, if the nature of this relationship could be found, then nanowire size could be directly measured by the interferometric microscope; even if the nanowire size was much less than the lateral resolution limit.

Dr Doug Little has developed this idea theoretically by applying principles of wave-optics to interferometric microscope systems. It turns out that diffraction is the key to understanding this deterministic relationship. Any microscopy expert will tell you that images are always imperfect replicas of an object. This is because imaging systems do not image point-like sources as points, but as a blurred spot defined by the impulse response (or point-spread function) of the imaging system.

As the image of an interferometric microscope is not perfect, it follows that the resultant measured height profile is not perfect either. The measured height at a given point actually turns out to be an average height weighted over the impulse response of the imaging system. The good news is, if the impulse response is known, the relationship between measured height and nanowire size can be theoretically derived.

With the theory Doug Little has developed, the relationships between measured height and any manner of particle geometry can be obtained. This can be done as a function of size, shape, position, and even material. And not just for nanowires. Other geometries such as spheres, pillars, trenches, steps and ridges can be modeled and calibrated. The important caveat of this measurement technique is that the geometry of the object surface or particle has to be known in advance.

Figure 2 – Colour-coded height profile of an Australian 5 cent coin. The profile was produced using the Bruker NT9800 optical surface profiler at Macquarie University (credit: Dr Doug Little and Mr. Adam Joyce).

Where will this capability be needed?

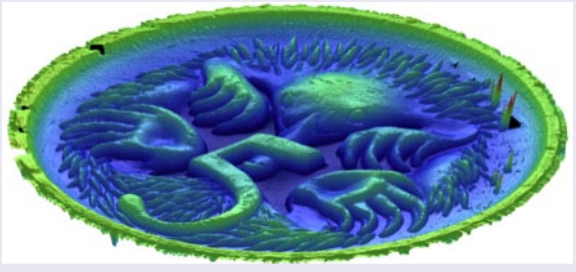
There are scientific and industrial contexts when the standard methods for nanocharacterisation such as electron microscopy and/or AFM are not very suitable, and it is in these circumstances that VIEWS nano-characterisation technique can really shine.

One example is where nanoparticles or structures are made from soft materials. Soft materials deform under AFM due to the force applied by the scanning probe, while the electron beams used in electron microscopy can cause damage to the sample. With VIEWS, soft materials can be studied without a problem because light interacts with such particles very weakly. A further example is nanoparticles immersed or embedded in transparent media

VIEWS measurements can be performed rapidly and can be readily automated which is an important consideration when scaling nanotechnology to industrial levels. Interferometric microscopy is also readily compatible with other microscopy techniques, and so can potentially be adapted into other sophisticated microscopy schemes.

In short, VIEWS can potentially be used to study nano-scale particles and structures where established nano-characterisation techniques are not suitable.

The VIEWS technique is in its infancy but its potential is clear. It is set to emerge as an important addition to the toolkit of researchers in studying the nano-scale.



NanoConnect - Providing a Bridge between Industry and University

Dr. Jonathan Campbell and Prof. David Lewis

Flinders Centre for NanoScale Science and Technology

Flinders University

Research and commercial interest in nanotechnology is driven by the unexpected ways that the properties of materials, such as colour, magnetism and conductivity, change when size is reduced to the nano-scale. While the term "Nanotechnology" is relatively recent, nano-scale materials have been used for a very long time in applications ranging from simple to highly complex. For example, the synthesis of colloidal gold has been known since ancient times, and was used for paints and potions in various parts of the world [1]. Nature remains the best nanotechnologist, with many examples of nano-scale structures in biology, such as on the surface of the water-repelling lotus leaf [2], and the structure of gecko feet [3] which is inspiring new types of adhesives.

The rapidly expanding "toolbox" of nanotechnology techniques has the potential to disrupt current approaches to manufacturing [4], and to enable bottom-up approaches using non-precious, abundant and low purity materials and lower cost manufacturing processes. The challenge has been getting some of these ideas to market so that companies can become more competitive domestically and internationally.

Nanotechnology opportunities exist in most sectors of Australian industry, however there is currently a significant gap between leading academic research and the capability in many Australian companies to take-up new or emerging technologies. In many cases, scientists, engineers and new product developers don't know the right questions to ask, or even what is possible. The NanoConnect program was developed by the Flinders Centre for NanoScale Science and Technology for just this purpose – to provide a means for companies to find out how nanotechnology can potentially help them and their products.

NanoConenct has now completed its first year and the model has proven to be a successful in generating industry-university interaction, and has shown that there are numerous unrealised opportunities for the commercialisation of new products and processes utilising relatively simple aspects of nanotechnology.

"With the challenges that the Australian Manufacturing industry are currently facing, it is crucial that local SME's can tap into high end University knowledge to ensure a successful migration to the next generation products that can be manufactured here in Australia for global markets."

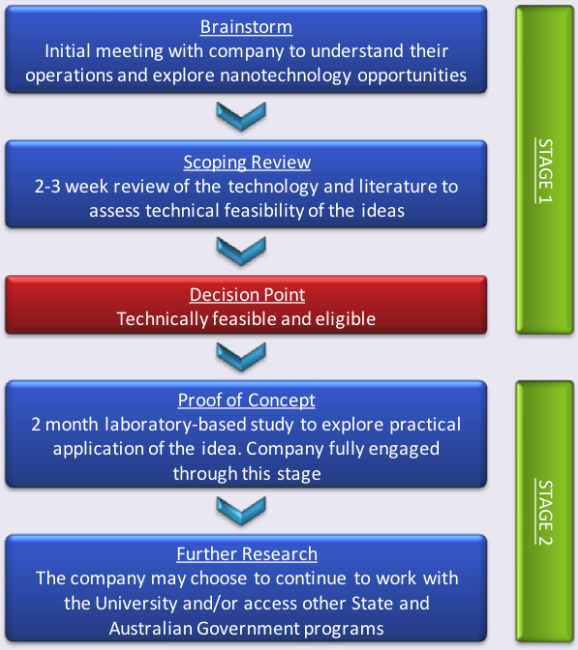
- General Manager, NanoConnect participant

What is the NanoConnect Program?

Innovation is about more than creating knowledge and ideas; it is also about applying knowledge and ideas in new ways to create value [8]. Therefore the ability of companies to collaborate with universities is an important part of the innovation process, and is a central theme among both State and Federal Government research, innovation and manufacturing policies. Funding for NanoConnect

was provided by DIISRTE through the National Enabling Technologies Strategy (NETS).

The process adopted for the Pilot Program is shown in the Figure below.



The two stage process has a decision point after an initial brainstorming and technology review to decide whether there is potential in the ideas that have been discussed with the company. If it is believed that there is real value to be created from further exploring the idea, then the project proceeds to Stage 2 with laboratory testing to prove the ideas have practical application. Subsequently, the participating companies may graduate into other existing government programs once the technical and business feasibility of the technology has been proven.

The NanoConnect program provides a complementary service that fits well with other existing innovation programs. Its role is to enable small and medium sized enterprises to access nanotechnology solutions, and to provide the opportunity to test the potential for ideas. Larger businesses are able to do this for themselves but, until now, smaller businesses have been unable to effectively access this knowledge.

"Your report previously sent was extremely detailed with plenty of information and references - this was much more than I had anticipated."

-Development Engineer, NanoConnect participant.

Importantly, we see NanoConnect as a mechanism for companies to find value in University interactions and the feedback shows that companies will be more than happy to invest in things that they can see the potential for a good return - the challenge is that many companies don't currently understand the value of interacting with Universities and don't know who to talk to anyway.

How did the Pilot Program perform?

The program received interest from 17 South Australian companies and three others from outside the state in the first year. Of these firms, 10 have completed Phase 1 technology reviews, through which nanotechnology opportunities were identified for all participants. Four of these have also gone on to undertake Stage 2 laboratory feasibility studies. Two of these firms are currently analysing the business potential of the ideas explored, and because they have had the opportunity to test the value of such collaboration, are now keen to continue to develop technological improvements and new products.

Companies that have been involved in the 2012 pilot program came from a range of sectors including defence, mining, aquaculture, printing, energy, industrial goods, food and construction. The companies saw great value being generated from their participation and the individuals involved felt as though they went away with many ideas for possible improvements.

In addition to providing access to University research resources, NanoConnect has established useful relationships between companies and the

University. Such collaboration benefits both parties and has begun to assist these companies to change their thinking about the ways they can create value through engaging with scientists.

The ability to provide for industry driven, varied and often short term project work has been a key success factor in the pilot program.

Conclusion

The success of the program so far suggests that there is a strong need, and that it is an enabler for other funding programs in the emerging technologies space – especially where there is a need to keep up to date with the rapid changes in such developing technologies.

The program was overwhelmed by the initial response and despite no advertising since the first week of the program, it continues to receive enquiries and requests to participate. This means that there is a great opportunity to broaden the program geographically and technically and provide help to a broader community.

One benefit of the program has been to open the eyes of University Researchers to some very highly challenging issues that are not usually reported in the literature – and many opportunities for world class research projects.

References

1. Sharma V, Park K and Srinivasarao M, Materials Science and Engineering R. 65 (2009) 1–38.
2. Salta M et al., Phil. Trans. R. Soc. A 368 (2010) 4729-4754.
3. Meyers M A et al. Prog. Mater. Sci. 53 (2008) 1-206.
4. Royal Society of Chemistry website, Nanotechnology, viewed February 2012.
5. Nanotechnolgy Enabling technologies for Australian innovative industries, 2005, Prime Minister's Science, Engineering and Innovation Council.
6. Enabling Technologies Roadmap Study, 2011, Australian Institute for Commercilisation.
7. Nanotechnology in Australia. 2009, Australian Academy of Science.
8. A Plan for Australian Jobs: The Australian Government's Industry and Innovation Statement, 2013, Department of Innovation, Industry, Science and Research.

Key Benefits and Learnings from the Pilot Program

1. Demand - There is a strong pent-up demand for such a program. There continues to be high industry demand shown after very limited initial publicity. This means that there are likely to be many more companies that would be interested in the program, and would benefit from involvement.

2. Building Relationships - NanoConnect is a high value method of introducing companies to university collaboration, only one of which had worked with a university previously.

3. Removing the Financial Barrier - Whilst companies are interested, they are reluctant to commit financially to research programs without some preliminary work that builds confidence. NanoConnect provides the opportunity to test a company's existing ideas, or generate new avenues to incorporate the latest technologies into their business, and therefore removes this barrier.

4. Accessing Capabilities - Companies, and especially SMEs, often do not understand University capabilities, how they might be useful and how to access them. Small companies in particular can be intimidated by Universities and may assume that academics are too removed from industrial practicalities. Initial exposure to industry experienced researchers can change this thinking permanently.

5. Wide Application - Interest has been from a very diverse range of (primarily manufacturing) industry sectors. Opportunities have been identified for all companies through Phase 1 with some of the projects having led to the identification of new product line opportunities, including significant export opportunities.

6. Further Research Intentions - Companies that have not previously contemplated further collaboration and grant opportunities such as Researcher in Business (RIB) are now doing so.


http://www.ausnano.net