Submission No 17

INQUIRY INTO NANOTECHNOLOGY IN NEW SOUTH WALES

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The Hon Tony Catanzariti
Chair
Standing Committee on State Development
Parliament House
Macquarie St
Sydney NSW 2000

Dear Mr Catanzariti,

Nanotechnology in New South Wales Inquiry

ANSTO welcomes the inquiry by the Standing Committee on State Development on nanotechnology in NSW, and appreciates the inquiry's multi-faceted nature, as ANSTO's involvement in nanotechnology is also multi-faceted.

ANSTO brings to the area of nanotechnology unique techniques, knowledge and intellectual property that provide answers to regulatory questions as well as help researchers and industry in understanding the nanoscience field and therefore the development of the latest nanotechnology.

NSW has potential to be a leading location for research and development of nanotechnology using the state-of-the-art research facilities and capabilities that are located within the State. In particular, neutron scattering using beams from our OPAL research reactor offers a unique way to look at materials at the nanoscale. This facility has potential to assist in advancing the development of new nanotechnology and our understanding of various nanotechnologies. ANSTO's facilities are used by researchers from universities, industry and other research organisations as well as our own research teams. Researchers in NSW investigating nanotechnology will have an international competitive advantage by virtue of proximity to OPAL, which will be among the top neutron scattering facilities in the world.

ANSTO is working with industry and universities in NSW on materials and process technology that incorporate nanomaterials. These investigations cross micro-, nano- and biotechnology fields. For example, we are developing novel materials with potential applications in solar cells, optics, optoelectronics and as protective coatings for abrasion and corrosion resistance. ANSTO's materials engineering researchers are also developing innovative detectors based on nanoscience that can be used in radiation protection, medical physics and radiobiological research.

Last year ANSTO established CeramiSphere Pty Ltd to commercialise ANSTO technology that can be used to produce ceramic nanosized particles that release an active ingredient at a controlled rate, over time ranges from hours to months. Applications include drug delivery, surface protection, cosmetics and nutriceuticals. For example, CeramiSphere offers potential for targeted delivery of drugs and other molecules to the precise location in the body where they are needed, with benefits for both patients and the healthcare system.

ANSTO also established Australian Membrane Technologies Pty Ltd last year to commercialise nano-particulate membrane bioreactor technology for wastewater treatment.

Particles can be labelled with radioactive elements ('radiolabelling') to track their movement, e.g. in a human or environmental system. ANSTO has developed radiotracer technology for assessing the toxicity of a range of novel and commercially available nanoparticles. The use of radiotracers is a major area of ANSTO's expertise. Because of the high sensitivity of radiotracers they are able to gain information about nanoscale interactions that cannot be readily achieved by other techniques. Hence they can provide information that can be used for advancing the engineering of new materials.

ANSTO contributes to nanotechnology development and education through the access that students and academics have to our facilities, the education and training programs that we run, and the role that our staff play in universities, e.g. as joint supervisors and adjunct professors.

We support public debate about nanotechnology, and are prepared to participate in suitable events or other forms of communication that might arise as a result of the current inquiry. For example, ANSTO has supported efforts by the Sutherland Shire Council to raise awareness in the community and educate the public about nanotechnology.

We would welcome a visit by Committee members and staff to see how our facilities and research contribute to understanding and development of nanotechnology. The facilities are impressive; for example, our small angle scattering instrument, which is relevant to nanotechnology research, is 40 metres long and at $4.5 million is most expensive of the nine instruments developed for OPAL. Last December, the Hon Verity Firth MP, who referred the terms of reference for this inquiry, visited for a general overview of our facilities and activities. Please contact our General Manager Public Affairs, Andrew Humpherson, on 9717 9041 or at andrew.humpherson@ansto.gov.au to arrange a suitable time to visit.

ANSTO would also welcome an opportunity to appear at hearings that the Committee arranges as part of this inquiry, to expand on any of the points raised in this submission or where the Committee regards ANSTO has having expertise. The contact in the first instance in this regard is ANSTO's Senior Adviser Research Management and Policy, Dr Miriam Goodwin, on 9717 3535 or at miriam.goodwin@ansto.gov.au.

Yours faithfully,

Dr George Collins

Chief of Research

Australian Government

ANSTO

Nuclear-based science benefiting all Australians

Nanotechnology in New South Wales:

Legislative Council inquiry conducted by the State Development Committee

Introduction

The Australian Nuclear Science and Technology Organisation (ANSTO) is a statutory authority within the Commonwealth portfolio of Innovation, Industry, Science and Research. It employs approximately 1000 staff, almost all of them based at Lucas Heights on Sydney's southern outskirts. Its size and its unique capabilities, including Australia's only research reactor, makes it a significant part of the innovation system in NSW.

ANSTO operates facilities that are used by researchers from universities, industry and other research organisations as well as ANSTO's own staff. Its research portfolio covers the environment, materials engineering, radiopharmaceuticals and a broad range of applications of neutron and x-ray scattering. The Organisation applies the outcomes of its research, in some cases through ANSTO-owned companies but mostly through providing services, expert consulting and contract and collaborative research to industry and public sector organisations. Each of these functions has an element involving nanotechnology.

Nanosized materials and technologies offer great promise, for human health and industrial and domestic products. Given the scale of nanotechnology materials, it is appropriate that the risks be properly taken into account. ANSTO's interest in this subject has five main strands.

1. Neutron scattering using beams from our research reactor offers a unique way to analyse materials at the nanoscale.
2. Our materials engineering capabilities are being applied to nanotechnology in

developing innovations and working with industry and universities. A key ANSTO capability is being able to synthesise complex materials, building on experience in radioactive wasteforms.

3. Last year we established a company, CeramiSphere Pty Ltd, that is commercialising nanosized particles.

4. Australian Membrane Technologies is another spin-off company of ANSTO. It is commercialising nano-particulate membrane bioreactor technology for wastewater treatment.

5. Particles can be labelled with radioactive elements to track their movement, e.g. in the body.

We address these topics in the framework of the inquiry's Terms of Reference.

Contents

Current and future applications of nanotechnology in the NSW community and industry

Analysis of nano-sized materials

Neutrons provide information on materials at the scale of atoms and molecules which can be invaluable to researchers, and the OPAL research reactor at ANSTO will be among the top neutron scattering facilities in the world. Researchers in this State will benefit from the proximity to this facility and the team at ANSTO. They will also benefit from interaction with researchers attracted to Sydney from around Australia and internationally to use the facility.

For example, neutron reflectometry can be used for analysis at a scale of 1 nanometre (nm) to 100 nm. Applications include examination of plasma polymer surface coatings and biological membranes.

Small-angle neutron scattering is a powerful technique for looking at size and structures of objects at 1-10 nm, such as that found in polymeric and biological materials, defects in metals and ceramics, pores in rocks and magnetic flux lines in superconductors. Small-angle scattering is complementary to electron microscopy – such as found at the Australian Microscopy and Microanalysis Research Facility.*

ANSTO and the Commonwealth Government have funded the development of the National Deuteration Facility at ANSTO as part of the National Collaborative Research Infrastructure Strategy; the NSW Government having been an important advocate for this Commonwealth funding. Neutron scattering is very good at 'seeing' hydrogen, which is an important constituent of organic and biological materials. There is a form of hydrogen called deuterium that has a similar chemical behaviour to hydrogen but can be detected using neutron scattering. So researchers use normal or deuterated samples, or put the samples in normal or deuterated environments, to see different features of a material. The presence of a national deuteration facility in NSW will be a great asset for the State to achieve international recognition for this type of research. Deuteration can play a role, for example, in a range of applications from the design and synthesis of

* Which was mentioned in the media release announcing this Inquiry.

hybrid materials or particles, to exploring the interactions of enzymes and their relationship to health or disease.

ANSTO is an investor in the Australian Synchrotron, as is the NSW Government, and has been extensively involved in its activities. Investors have rights to access, which is a valuable resource for nanotechnology R&D by NSW-based researchers. ANSTO also facilitates access to synchrotrons overseas, funded through two Commonwealth programs.

Some more examples of current research on applications of neutron and x-ray scattering concerning nanoscience and nanotechnology are attached.

Materials engineering

ANSTO researchers are helping industry by developing understanding of the relationship between the molecular structure, porosity and function in the engineering of materials.

Using state-of-the-art scientific instruments and tools, researchers are developing novel materials as porous media, nanoparticles or thin-films that are compatible with polymer and biological surfaces. These materials have potential applications in solar cells, optics, optoelectronics and as protective coatings for abrasion and corrosion resistance.

A key ANSTO capability is being able to synthesize complex materials using novel process technology. This capability derives from the Organisation's experience in the development of wasteform materials for the nuclear fuel cycle. Materials and processes developed for waste remediation can also be applied to battery technology and to hydrogen fuel cells.

Nanoparticle technology

CeramiSphere's technology has evolved from ANSTO's long held expertise in ceramics processing. Currently wholly owned by ANSTO, CeramiSphere Pty Ltd is also located at Lucas Heights but is seeking investment with the intention of spinning off from ANSTO.

CeramiSphere provides controllable release of active molecules from ceramic micro and nano particles for a wide variety of applications, including drug delivery, encapsulation and controlled release of chemicals for surface protection and delivery of actives for cosme/nutriceutical applications. CeramiSphere's patented technology encompasses the room temperature encapsulation of active materials inside ceramic spheres and their controlled release over hours to months.

CeramiSphere's technology enables it to produce a wide range of particle sizes, ranging from less than 10 nm to 100 microns. For example, the same biocide can be encapsulated at the nanoscale for use as a wood impregnator, at a larger size for use in paint and larger again for mixing with concrete.

During encapsulation, an active ingredient is trapped within pores of the particle matrix. The internal structure of each particle is similar to a Swiss cheese, with the pores as its holes. Physical characteristics of the cheese or mesh – such as density, pore size and structure – can be tailored. By controlling the size of these holes and the rate at which encapsulated material can diffuse out, CeramiSphere can precisely control the release rate of an active ingredient.

CeramiSphere is working with a range of large international companies on product development projects and is assessing its technology in such areas of interest as topical drug and vaccine delivery.

Wastewater treatment

Another spin-off company of ANSTO, Australian Membrane Technologies Pty Ltd, is commercialising nano-particulate membrane bioreactor technology for wastewater treatment. Compared to municipal systems for wastewater treatment, this company's technology offers savings up to 60% in water reuse and significantly cheaper operation.

Health, safety and environmental risks and benefits

Radiolabelling of nanoparticles

An understanding of how existing nanomaterials can interact with biological systems to initiate a toxic response will enhance our ability to determine the risk of adverse effects.

Understanding of effects on human health has not kept pace with the rapid growth in the development, manufacture and use of nanomaterials. The rapid uptake of this promising technology in a wide variety of products means increases in exposure and there is some evidence that nanoparticles can exert adverse effects upon cells and tissues. It is important robust and reliable methods are established to assess the toxicity of these nanomaterials and develop appropriate regulation for their safe use and handling.

Radiotracers can be incorporated into nanoparticles or attached to their outside. (It is important that the chemical structure and reactivity of the nanoparticle is not changed.) The extremely high sensitivity of radiotracers makes them ideal for radiolabelling of nanoparticles. The particles can then be tracked as they move within humans and environmental systems, using cameras that are designed for imaging radiotracers (e.g. as used in hospitals and nuclear medicine centres).

The radiolabelled nanoparticles can be tracked on the surface of solids, such as soils, in the air and in solutions containing a mixture of chemicals. The radiotracer technology can be adapted for fast, accurate and high-throughput for risk assessment of nanoparticles.

ANSTO has established a collaboration with the Australian Institute of Bioengineering and Nanotechnology at the University of Queensland to assess the biopathways of nanoparticles in humans and the environment. To date the team has had considerable success with radiolabelling of nanoparticles and feedback internationally has been very positive.

There are three major challenges that face researchers attempting to determine the biosafety of nanomaterials.

1. There are no agreed approaches to investigating adverse effects of nanoparticles. To address this, a series of international workshops have been held and consensus recommendations have been made. Of greatest importance is the need for basic research to determine the molecular characteristics of nanoparticles that dictate their interaction with biological systems. ANSTO and its collaborators are developing a library of precisely engineered nanoparticles with different size and surface characteristics for this purpose.

2. Extensive analysis of the characteristics of nanoparticles is essential.

3. Labelling of nanoparticles for visualisation and tracking at ultra-low concentrations has been difficult and has required some innovative chemical approaches, such as those developed at ANSTO.

How particle size makes a difference

In healthcare, different therapeutic treatments require different modes of drug administration. For example, intravenous treatments require nanoparticles to deliver the therapeutic, while treatments for lung conditions are more suitable in larger particles.

CeramiSphere's novel nanotechnology offers potential for targeted delivery of drugs and other molecules to the precise location in the body where they are needed. Far more of the payload is likely to be retained and protected as it passes through the body to the targeted organ. This could lower the risk of side effects and increase the amount of active material delivered to the target. Being able to control the delivery of a drug over a given time period also reduces the frequency of dosing, which increases patient compliance and reduces healthcare costs.

These protective and targeting capabilities are being exploited in the development of new formulations for oral delivery of proteins, wound healing, vaccine and gene-therapy.

Appropriateness of the current regulatory frameworks in operation nationally and in NSW for management of nanomaterials over their lifecycle

Nanoscale products are applicable across a wide range of industry sectors and therefore many regulatory frameworks will be involved. A key issue is awareness among regulatory agencies of the potential implications, so they can factor that into their decision-making.

The size, chemical composition and surface properties of nanomaterials primarily determine their interaction with biological systems and potential toxicity. This raises regulatory issues that form part of the context for the radiolabelling study discussed above.

Education and skills development related to nanotechnology

ANSTO is Australia's most significant individual source of skills development and education in neutron scattering and radiolabelling, as well as playing an important role in development of skills in ceramics. Materials engineering researchers also assist universities in training scientists for careers in nanotechnology in the disciplines of chemistry and materials science, emphasising the structure-function properties of nano-scaled materials.

ANSTO is developing skills in the State in nanotechnology through:

- Access to ANSTO facilities by academics and students via the Australian Institute for Nuclear Science and Engineering – For example, at least 24 publications involving nanotechnology or nanoscience were produced through in 2007, and the radiolabelling research team discussed above includes a University of Queensland PhD candidate
- Postdoctoral fellowships – ANSTO currently hosts a postdoctoral fellow through the University of Wollongong, funded by the Australian Research Council, who is working on micro- and nano-scale radiation dosimetry (dose measurements)
- Participation in Cooperative Research Centres – such as the CRC for Polymers
- Hosting Year in Industry students
- A summer placement program for 12 weeks
- Industry placements for a fixed term, typically six months
- Joint and adjunct positions at universities – 25 such roles currently being held at universities in NSW
- General outreach to universities and schools

Access to ANSTO's facilities is determined by peer review of research proposals. This encourages research excellence but means that whether the facilities are used for nanotechnology in particular is determined by the quality of proposals coming forward in this field. That in turn is shaped by wider factors, such as funding for university teaching and research in this area, and the regulatory environment in which that teaching and research take place.

ANSTO does not charge for neutron scattering beam time if results are published in the open literature. Access for proprietary work is available on a fee-for-service basis.

The level of community understanding of nanotechnology and options to improve public awareness of nanotechnology issues

A wide range of information about the contribution that ANSTO's neutron beam instruments makes to characterisation of nanosized materials is available on ANSTO's website (www.ansto.gov.au). CeramiSphere has its own website with extensive information about applications of its technology (www.ceramisphere.com).

ANSTO has supported efforts by the Sutherland Shire Council to raise awareness in the community and educate the public about nanotechnology. A highlight was participating in two events at the Sutherland Shire Hub for Economic Development (SsHED) in Loftus. ANSTO instigated the involvement of CSIRO in these events. These fora highlighted the potential for growth and opportunities in nanotechnology as well as the social and ethical challenges facing community acceptance of nanomaterials. Representatives from small and medium-sized enterprises were briefed on the potential applications of nano-scale materials and their synthetic processes. Considerable interest was expressed at this seminar and several follow-up technical discussions took place. Many of the audience asked how nanotechnology can integrate with and impact on existing products and businesses.

ANSTO appreciates the importance of public debate on this topic, and is prepared to participate in suitable events or other forms of communication that might arise as a result of the current inquiry.

Conclusion

The inquiry by the Standing Committee on State Development of the NSW Legislative Council is an important step for highlighting the range of activities under way in this State; the potential to build on the State's capabilities; and ways in which concerns regarding nanotechnology risks might be addressed.

The applications are diverse, as witnessed in the potential uses of CeramiSphere's technology alone. The prospect for major improvements in human health and industry are enormous. However, materials do behave differently at the nanoscale and it is important that this be properly understood and taken into account in regulation. Indeed, it is this property that gives nanomaterials their attractiveness yet at the same time demands that they be treated differently than their conventional counterparts.

Nuclear science and technology offer unique tools to investigate nano-sized materials, to develop them and to see how they behave when they are put to use. ANSTO's facilities and expertise therefore are an important feature of nanotechnology capabilities in NSW and of national and international efforts in this field.

Attachment

ANSTO neutron and x-ray scattering research

Neutron and x-ray scattering science involves studying the structure and the dynamics of matter on a length scale from atomic dimensions to a few thousand nanometers, which is largely identical with the range relevant for nanotechnology.

The following examples of ANSTO's neutron and x-ray scattering research relate to nanoscience and nanotechnology, and all involve collaborations between ANSTO and Australian and international universities and research organisations.

- ANSTO's **Neutrons for the Hydrogen Economy project** couples neutron-scattering tools and experts at ANSTO with external collaborators studying alternative energy systems and materials. In the nanotechnology context, questions arise across areas crucial to the realisation of a 'hydrogen economy': for example, in the storage of hydrogen in key materials, in energy production, and in the performance and lifetime of fuel cells.
- **Magnetic thin films and spintronic materials** – Neutron scattering will be important in the development of materials based on 'thin-film', such as magnetic materials to improve the efficiency of energy delivery systems, e.g. motors and transformers; magnetic recording media; magnetic sensors for computers; and new magnetic memory technologies.
- **Nanomagnetic materials** – Developments regarding magnetic particles in the nanoscale could, for example, open the way for the development of quantum computing – which is an area in which this State has significant capabilities. The application of nanomagnets goes from the electronics industry to the biomedical/biotechnological field, including magnetically targeted drug delivery, magnetic hyperthermia treatment and novel biosensors. Magnetic nanoparticles coated with proteins or polymers offer tantalising possibilities. In the future the combination of organic and organic assembled magnets could open the way to a new class of self-assembled magnetic structures.