

Section 1

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President's Report

At the outset of this report, I would like to offer my sincere thanks to Dr Ian Smith (Executive Director, ANSTO) and his colleagues, as well as the AINSE Executive and Council for promoting a very positive spirit in discussions of new projects and the evolution of AINSE's mission during the years that I have been President. The developments in Australia, particularly at OPAL and the Synchrotron, greatly increase Australia's profile in our region. Further enhancement of that will come if we can join in major Asian projects, such as the J-PARC facility in Japan, which will be one of the world's best accelerator driven facilities for nuclear physics and materials science.

The achievement of full operating power of the OPAL reactor on the 3rd of November 2006 was a major milestone for Australia. In listing the expected benefits of the reactor, the Australian Academy of Science in 1994 put the "national interest" at the top in its recommendation to the Australian Government. The correct finance for the project, the skill in its construction and the proper deployment of instruments and personnel should allow that benefit to be realised.

At the Executive Committee in September 2003, AINSE considered its potential interaction with the Australian Synchrotron. That instrument has now reached the target intensity for its beam power and appears to be very well constructed. Its proper deployment under truly contestable conditions should be a complementary strength to OPAL in Australian materials science and industry. AINSE welcomes the appointment of ANSTO with industrial partner WorleyParsons as the operators for this facility.

The AINSE Research Fellowship Scheme operated for the first time in 2006. This scheme is meant to attract highly creative scientists nationally and internationally to become the future leaders in Australasian universities of programs at OPAL and other ANSTO facilities. A very strong field, about a third of whom were international was attracted in collaboration with AINSE member universities. The conditions of "tenure track" for their appointment were accepted by the universities who joined in the nomination process to the Selection Committee. Two Fellows were appointed but the field was so strong that all in the long short list were appointable. AINSE believes that it is as important for the "national interest" to build the "human infrastructure" as the "material infrastructure".

AINSE has continued to strive to ensure increasing quality of impact in the work done through its operations. The "bench marking" process was extended for 2006 to the Geoscience and Archaeology Specialist Committee area. With the forthcoming Research Quality Framework of the Australian Government, AINSE hopes to ensure that university work done at ANSTO adds significantly to the quality indices of our researchers.

AINSE has continued its international connection in the neutron scattering area with the ISIS Spallation Source in the United Kingdom, which will shortly commission its second target station of unique cold neutron scattering instruments. This was reviewed formally by the Australian Research Council in February 2006. This international access has provided the Australian "soft matter" community with facilities not available in Australia since 2002. The community has consistently out-performed expectations in the contestable selection process of proposal selection at ISIS. The photograph shows the President with Susan Pearce, the first AINSE Postgraduate scholar to achieve funding by herself for a proposal to the ISIS facility on strain testing of engineering materials. She is a student of Dr Valerie Linton in the Department of Engineering of the University of Adelaide.



The specialist committees have also shown increased rigour in their selection of proposals. AINSE was very pleased to have new nominations of high calibre for the Specialist Committee, at the change over last year. A full scientific program was completed in 2006.

The Winter School deserves special mention as an aspect of AINSE's quality process. Again it was a great success and the contribution of Professor Gerald Laurence, as well as the ANSTO staff who teach at the School, must be recognised. The high achieving young Australians who attended meet in an informal and challenging process.

AINSE has been involved in Australian Government initiatives this year.

- A submission was made to the Uranium Mineral Processing and Nuclear Energy Review (UMPNER) focusing on potentially needed skills.
- AINSE participated in the public debate on nuclear energy in the media and academia.
- AINSE has progressed the project for a "Nuclear School" - agreed upon at the June 2006 Council, with University and ANSTO partners.
- AINSE's submission to the National Collaborative Research Infrastructure Scheme (NCRIS) foreshadowed the absolute need to provide travel and accommodation funds against a profile of growth, the OPAL reactor program (and by implication the Synchrotron program). The great failure of the first round of the Australian Government's Major National Research facilities program (1995) was its failure to allow operating funds for the funded capital projects. It is in the "national interest" to make the fullest and most contestable use of the major facilities now created.
- AINSE was active at the OECD Working Party on the Future of Nuclear Physics (November 2006), Professor White, as the Australian member, was able to show something of the applied nuclear physics done through the AINSE project and achieved support from other members of the working party for whom the applied component of nuclear physics was very important.

Amongst AINSE supported conferences in 2006 was that on plasma physics and Australia's opportunities for entering the International Thermonuclear Energy Reactor (ITER) program is worth noting. The need for coherence in the Australian program and a proposal for Australia to contribute to the international program in some associate status was discussed. AINSE also was a sponsor of the FEAST conference, November 2006, "Research Without Borders" and provided partial support for the visit of Professor Sir Christopher Llewellyn-Smith to talk there on fusion-related matters.

I am very glad to welcome Professor Brian O'Connor as the new President of AINSE and Professor Allan Chivas as the new Vice President. In 2006 we have divided some of the work, and the pleasure of working so closely with them has been very attractive.

Professor John White
President, AINSE



Professor John White and AINSE postgraduate scholar Susan Pearce

Scientific Secretary's Report

This period of writing the Scientific Secretary's report is an exciting one principally because this is the time when we start to receive AINSE awards progress reports for the year under review.

These progress reports constitute one tangible manifestation of the AINSE system in operation. Our requirement that progress reports are grounded on quantifiable results ensures that as they are received we can evaluate the breath and quality of research undertaken.

AINSE Postgraduate Research Awards are granted to postgraduate students whose research projects are associated with nuclear science, or its applications, and require access to the unique national facilities at the Lucas Heights Science and Technology Centre. I am pleased to report that 12 new postgraduate students were added in 2006.

The awarding of two AINSE research fellows, the first since 1993, during the year was an exciting milestone for the Institute. The two fellows, Dr Darren Goossens at The Australian National University, Research School of Chemistry and Department of Physics and Dr Daniel Riley at The University of Melbourne, Faculty of Engineering (Mechanical) with an honorary position within the Bio21 Institute, were selected from a strong field of applicants which included people from all over the world.

AINSE continued to play a pivotal role in conference activities during the year. I see AINSE's involvement as threefold. Firstly, AINSE encourages, promotes and provides initial assistance to conference organisers. Secondly AINSE plays an active role, organisationally, in selected conferences and thirdly AINSE underwrites conferences that are considered to be worthy of such support. In this context AINSE underwrote and provided active administrative and organisational support to the Australian ITER Forum Workshop held in Manly from 11-13 October 2006. The workshop brought together international ITER team-members, Australian industry, research community and government to discuss how Australia can be involved in constructing, operating and using ITER. The workshop is considered to be a success both in terms of its content and impact and also because it made a small profit that has been reinvested in developing a strategy for Australian involvement in ITER. I am pleased to report that conference management expenses of \$106,368 were more than covered by sponsorships and conference registration fees of \$130,649.

2006 saw the full integration of our New Zealand Members and their research input is reported in Section 2. Together with Professor John White, AINSE President 2005 - 2006 I visited the Universities of Otago and Canterbury and GNS Science to discuss collaborative research opportunities. I consider that face to face contact with representative member universities to be an essential feature of my duties and during the year I visited 13 other campuses.

I am pleased to report on the success of AINSE's Winter School at ANSTO held in July 2006. The Winter Schools, which involve a mixture of lectures, experimental sessions and demonstrations and includes hands-on experience in experiments, provides a high level intellectual 'cauldron' for our emerging young researchers. Feedback from participants indicates that the ratio of complexity/introductory nature of the topics was at about the right level.

AINSE continued to act as a peak body on behalf of its member organisations in applying for external grants. Examples include: a ARC Linkage Infrastructure and Equipment Fund Grant to assist Australian Researchers to gain access to ISIS, which is the world's most powerful pulsed neutron source and is located in the UK; and an International Science Linkages grant to support the ITER workshop.



The Institute continued its promotion of emerging university educational opportunities in the area of nuclear science and engineering and in the period established a home page resource to publicise this area.

AINSE President Professor John White's two year tenure as AINSE President concluded in December 2006. John's dynamic support and breath of knowledge and experience was a valuable asset for the Institute. Professor White will be followed by Emeritus Professor Brian O'Connor of Curtin University of Technology as AINSE President

Council and Committees

On AINSE Council the following changes occurred during 2006

ANSTO's Anne Henderson Sellers and Ron Cameron replaced by Peter Holden and George Collins

Monash University's Trevor Hicks replaced by Robert Norris

Murdoch University's Stephen Thurgate replaced by Danielle Meyrick

Deakin University's Pip Hamilton replaced by David Stokes

Australian Catholic University's Neil Saintilan replaced by Brian Bicknell

We also welcome Otago University's Glenn Summerhayes to the Council.

AINSE continued the process whereby membership of the five specialist committees is refreshed while ensuring that there is continuity. During the year there was at least one change on each of these committees. Membership details of the specialist committees is outlined on pages 6 and 7 of Section 2 of this report.

AINSE and I remain grateful for the enthusiasm and generosity of all those who contributed to the various committees and Council. Their considerable input is critical to the onward development of the institute.

Finances

In 2006, operating revenue of \$5,272,409 was made up of \$2,483,275 from membership fees, \$2,479,004 from external grants, \$171,882 from interest, \$135,039 from conference income and \$3,209 from other sources. In line with practice membership subscriptions are reviewed on an annual basis to determine AINSE support for each university. On average, for the period 2000 to 2006 inclusive, universities received research and training benefits amounting to 3.24 times their subscriptions, which is the same as that reported last year.

AINSE's operating expenses in 2006 were \$6,264,732, leaving a planned deficit for the year of \$1,026,255. The majority of the deficit is accounted for by the hand over of STAR. If the deficit met by AINSE this year, \$881,498 is taken out of the equation then the deficit is of the order of \$100,000 which is close to the budget set by the Council. See figure 1 for details.

The majority of AINSE funds are normally used to facilitate travel and access to Lucas Heights for university researchers and their research students. In 2006 Research Awards were \$1,757,163, a significant increase over the figure for 2005 of \$1,464,493. Postgraduate Scholarships worth \$462,229, represents small decrease on the 2005 figure of \$515,464.

The Financial Statements for the calendar year 2006 in section 2 of this report were prepared by ANSTO Finance and audited by Mr David Aston of Escott Aston and Co.

Awards and postgraduate research awards

A total of 211 Awards were funded in 2006 and another 88 were carried over from previous years. Figure 3 shows the distribution of 2006 AINSE awards by specialist area. Research highlights in each of the specialist areas are given below on pages 6 to 15. Progress reports for each of the projects can be found on our home page. Of the 211 2006 Awards 175, or 83% were conducted in collaboration with ANSTO. First time award holders in 2006 represented 36% of the cohort, which is a considerable increase on the past few years. I attribute this continuing high influx, in part, to the diligence of our Councillors and to my ongoing university visit program; in 2006 I spoke with researchers and students at 19 member campuses in Australia and New Zealand. My thanks go to the Councillors without whom these visits would be much more difficult to organise and not nearly as effective.

In 2006, 12 of the 57 AINSE postgraduate research award holders received an award for the first time. During the year five PhD theses were received and two candidates withdrew. The AINSE postgraduate research award holders accessed the facilities for a total of 1035 days. In addition, another 199 students gained access to the facilities via awards held by their supervisors for a total of 1247 days.

In the period we record 466 papers of which 215 were published in refereed journals, 10 books or chapters of books; and 64 theses not previously reported. Details of publications can be found in section 2 of this report.

Acknowledgements

I thank Dr Ian Smith who has provided practical advice throughout the year and supported AINSE in many ways. I also extend my thanks to all those from the universities and ANSTO, there are far too many to name individually, for their help and advice throughout the year.

In the AINSE Secretariat Rhiannon Still, Nerissa Phillips, Sandy O'Connor and John Studdert have continued to work hard to preserve the long standing reputation of a friendly, supportive and accommodating secretariat.

Dennis Mather

Scientific Secretary

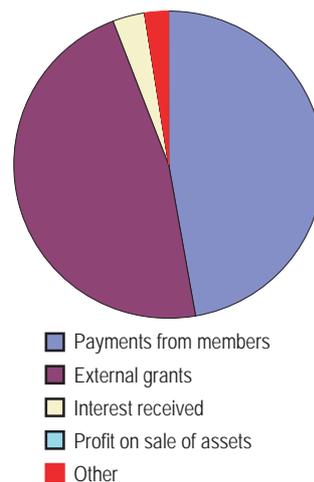


Figure 1 Operating Revenue

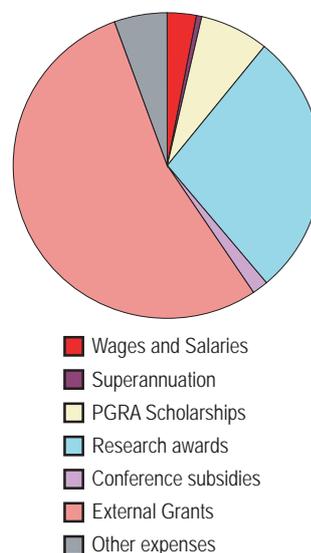


Figure 2 Operating Expenses

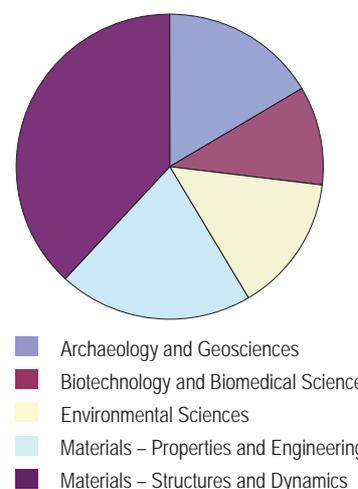


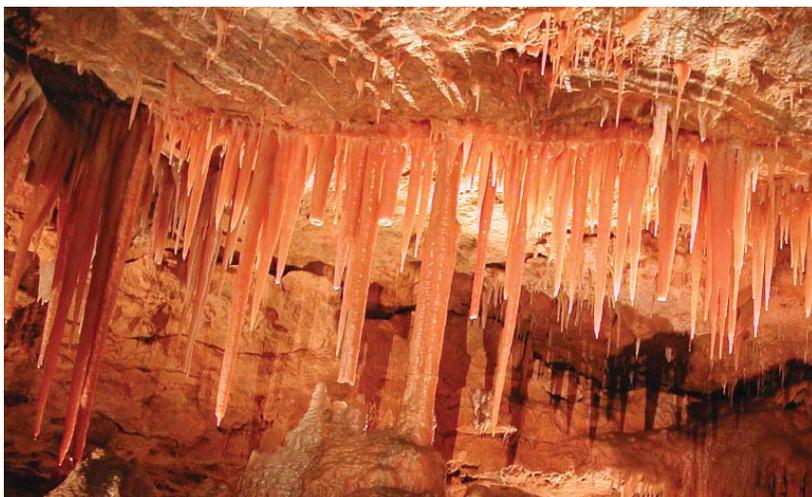
Figure 3 Awards Expenditure by Specialist Area

Research Highlights

Archaeology and Geosciences

Carbon-14 dating of stalagmites

Radiocarbon (^{14}C) dating is a powerful method for determining the age of a wide range of materials for archaeological, geological and past climate studies. However, due to changes in the amount of radiocarbon in the Earth's atmosphere over the past 50,000 years it is necessary to calibrate radiocarbon dates. Unfortunately, the current internationally-agreed calibration dataset (IntCal04) only applies to the last 26,000 years and beyond this, measurements of radiocarbon variations from differing archives disagree. Thus radiocarbon dates between 26,000 and 50,000 years ago, vital for determining the first peopling of Australia, long-term drought cycles and other important questions, may be inaccurate by thousands of years.



Baigu Cave, South China

Dr Jian-xin Zhao of the University of Queensland and Dr David Fink at ANSTO have undertaken paired measurements of radiocarbon (using AMS techniques at ANSTO) and uranium-series (using TIMS methods at University of Queensland) on a stalagmite from Baigu Cave, South China to look at this key time period. They found that their radiocarbon variations agree well with other estimates up to 26,000 years ago but between 26,000-30,000 years ago they saw some very large and quite rapid fluctuations. These could be caused by changes in the production of radiocarbon (due to variations in solar activity, the Earth's magnetic field or intensity of cosmic rays) or the global carbon cycle itself (ocean circulation being the main protagonist). Their record provides new information about these systems, and also contributes to international efforts to build a reliable radiocarbon data set beyond 26,000 years ago.

The lost pines of Luzon

Up to about 5000 cal yrs BP a *Pinus* forest, which today is only found at 600 m above sea level, grew in close proximity to Paoay Lake, a large coastal lake in Ilocos Norte, North-western Luzon. At this point the forest suddenly disappeared and was replaced by secondary forest and grassland. This landscape change precedes the start of the Neolithic record for Luzon and occurs at a time when there is no significant climate shift for the region. Pollen grains and charcoal particles that have accumulated in lake sediments over time have been used as proxies of vegetation and fire occurrence in the landscape. Although there is no strong evidence as yet for agricultural activity in the record, grass pollen in the same size class as rice dominates after 1800 yrs BP. Therefore, in an attempt to disentangle the relative contributions of human activity and climate change in this record, Dr Janelle Stevenson of the Australian National University is making 180 measurements on the diatom fraction in collaboration with Dr Melanie Leng of the British Geological Survey to produce a paleo-precipitation record. Other work is being done using phytolith and macro-botanical analyses to identify possible cultivars.

Stevenson is primarily interested in agricultural activity and the hypothesised Neolithic expansion out of Taiwan.

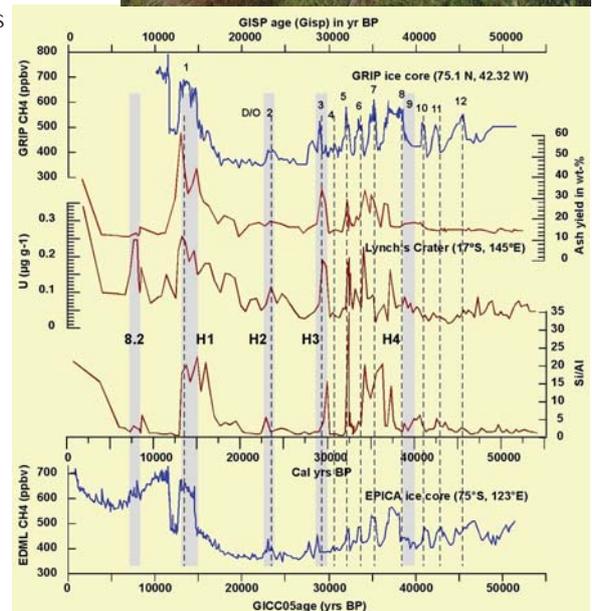


Taking samples in Lake Paoay for ^{210}Pb analysis

Climate change recorded in peat and lake sediments in NE-Queensland

Peat and lake deposits have been recognised as valuable archives of past environmental changes. A multidisciplinary research group at James Cook University under Dr Raphael Wust and at Monash University under Professor Peter Kershaw is investigating the crater lake sediments of Lynch's Crater in NE Australia, which contain both lake and peat deposits and laid down over the last 240,000 years. Several climate "proxies", that is recorders of climate variability, such as pollen, diatoms, trace metals, are being investigated and will contribute to a better understanding of our past climate and its variability. The project includes several post-graduate students and an honours student, including Joanne Muller (JCU), Malin Kylander (Imperial College), Sue Rule and Sophie Bretherton (both Monash).

AINSE post-graduate scholar Joanne Muller focused on determining the use of geochemical proxies to decipher climate fluctuations and environmental changes in the top 13 metres of peat deposits. Thirty-five AMS dates were determined at ANSTO that formed the robust chronology for the last 55,000 years. During that time, both major and trace elements revealed a clear link between major global climate changes and changes recorded in the Lynch's Crater deposits. For example, several large-scale ice-discharge events occurred in the North Atlantic, the so called Heinrich events, that changed the global ocean circulation influencing climate patterns around the globe, see GRIP ice core data in adjacent Figure. The Lynch's Crater data show that some peaks of the proxies used lead and some lag the ice core records, eg GRIP, EPICA, illustrating the possibility that the tropics may have triggered some of the global climate changes while others may represent the feedback of, for example, freshwater discharge in the North Atlantic. Heinrich event 1, H1 in the figure, shows a long lead up in ash yield and U concentration in Lynch's Crater starting around 17,000-20,000 years ago illustrating that changes occurred in the tropics long before the massive freshwater discharge during H1. Other proxies, such as the Si/Al ratio, see the adjacent figure, are more in line with some of the changes recorded in the ice cores. Current studies of the core are extending the record back and will provide a direct link to climate changes as recorded in low latitude between the last two interglacial and glacial periods.



Rise and Fall of the Antarctic Ice Sheet

In the context of a warming global climate it is particularly important to understand the behaviour of the Antarctic Ice Sheet (AIS) in response to changing climate. This is important because the AIS has the potential to make a very large contribution to global sea level change.

The best way to understand how the ice sheet will respond to a changing climate is to investigate how it has responded to climatic changes in the past.

For the past million years or so the Earth's climate has fluctuated periodically between relatively cool periods (known as glacial), and relatively warm periods (known as interglacials). We are currently in an interglacial period, where large ice sheets are present only in Antarctica and Greenland, as opposed to glacial periods where large, continental ice sheets covered much of Eurasia and North America, resulting in global sea levels 120m lower than today's.

By measuring the concentration in rock surfaces of certain rare radiogenic nuclides (in this study ^{10}Be and ^{26}Al), we can determine the period of time for which these surfaces have been exposed, which tells us how long it has been since the ice sheet retreated from a particular location.

A team of researchers including AINSE postgraduate scholar Kat Lilly and Kurt Lambeck of The Australian National University, Derek Fabel of the University of Glasgow, and David Fink at ANSTO collected rock samples from glacial landforms at various sites within the East Antarctic Ice Sheet, and analysed them for their ^{10}Be and ^{26}Al content on ANTARES at ANSTO. These measurements, combined with field mapping of glacial landforms, allow us to put constraints on the timing and extent of past changes in ice volume in East Antarctica, and therefore to learn something about how the ice sheet responds to climate change.



Image caption: Collecting rock samples in the Grove Mountains, interior East Antarctica.

Research Highlights

Biomedical Science and Biotechnology

Development of radiolabelled PAI2 derivatives for imaging tumour metastases

The high rate of mortality in cancer is a result of invasion and metastasis and the failure to detect and eradicate micrometastases after local cancer treatment, such as surgery or irradiation. To date there are no non-invasive tests that can detect and measure metastatic potential of tumours in individual patients. In a collaborative project between the University of Wollongong and the Radiopharmaceuticals Research Institute, researchers are developing novel non-invasive tumour imaging agents based on a non-toxic protein Plasminogen Activator Inhibitor (PAI2) that specifically identifies a critical marker of malignancy. PAI2 has been labelled with commonly used imaging radioisotopes technetium-99m and iodine-123/124 and evaluated for its ability to detect and distinguish malignant from non-malignant tumours using mouse models of human cancer. SPECT-CT imaging and biodistribution have been undertaken to determine the kinetics and tissue distribution of labelled PAI-2 in mice with and without xenografts of various tumour cells. Results from these initial studies indicate that radiolabelled PAI2 exhibits favourable pharmacological behaviour as a radiotracer and warrants further investigation.



Figure 1 Protein Structure of PAI2 showing classical serpin conformation

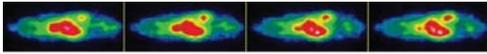
The increased expression of uPA plays a key role in tumour invasion and metastasis. Tumour cell surface uPA has been proven to be a critical marker of these processes and it is now recognised as having strong prognostic relevance, as well as being a therapeutic target. In this research project the uPA inhibitor, PAI2, targets and accumulates in human tumours and hence has potential in imaging as well as therapeutic applications.

A significant outcome in this project would be a PET and SPECT radiolabelled PAI2 derivative with the ability to image tumour masses with metastatic potential compared to normal cells and benign tumours, which contain little or no uPA. While nuclear medicine imaging techniques such as SPECT and PET can detect sub-clinical tumours, PAI2 would be very specific for cells with metastatic potential. Thus, within the limitations of the existing imaging technologies, PAI2 may provide a more sensitive detection technique for early stage tumours that are likely to metastasise. Quantification by imaging of PAI2 tumour uptake using iodine-124 or fluorine-18 PAI2 analogues, hence uPA expression, should provide a quantitative index which may be useful in prognostic algorithms.

Work under this project is aimed at optimising the efficiency and resolution of a potential new functional imaging system, which gives information about tumour invasion and metastasis. The technique exploits two key biological facts: (1) that urokinase plasminogen activator (uPA) is a potent marker that predicts metastatic potential in multiple human tumours, together with (2) the uPA targeting selectivity and lack of non-specific toxicity of plasminogen activator inhibitor type 2 (PAI2).

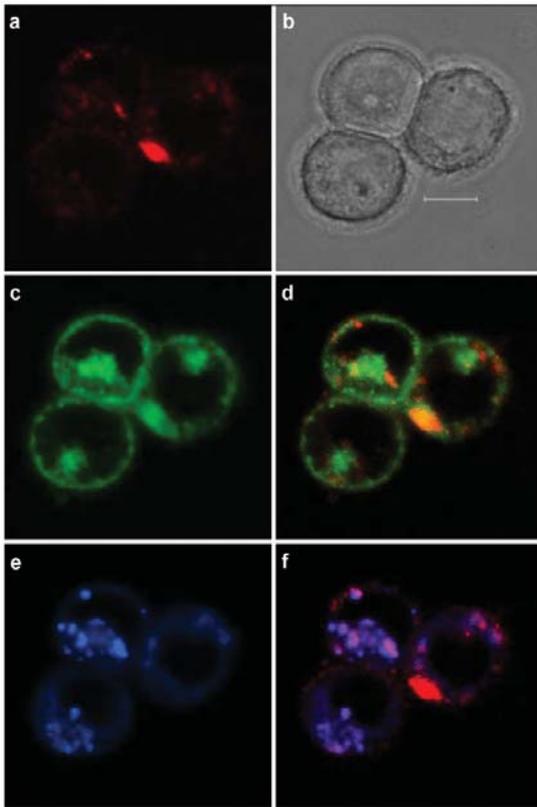
There is currently no technique like this available elsewhere and thus this represents a potentially important breakthrough in tumour diagnostic methods.

Figure 2 Biodistribution of iodine-123 labelled PAI2 in PC3 tumour bearing mice 25 min



after administration showing rapid distribution of PAI2

Figure 3. Specific internalization of PAI2 (red, a) into prostate cancer cells allows the



intracellular delivery of radiolabelled PAI2. Orange (d) and pink (e) colour indicates colocalisation of PAI2 within endosomes (green) and lysosomes (blue) proving that PAI2 has been taken up by a specific process into the cells. (b) Transmission image, the rest are confocal microscope images.

Research Highlights

Environmental Science

Ferns clean-up arsenic contaminated soil

The historical use of arsenate salts as herbicides and insecticides, particularly in the control of cattle ticks, has left a legacy of contaminated sites throughout Australia. For example, there are over 1600 decommissioned cattle dip sites in northern NSW, with up to 3000mg As/kg of dry soil.

Phytoremediation is one approach to heavy metal pollution. Plants are used to extract, sequester or detoxify contaminated soil. Arsenic hyper-accumulation by a plant was first reported in 2001. The fern *Pteris vittata* has been shown to be very efficient at extracting arsenic from contaminated soils. It has been assessed to contain 8,960 and 27,000 micrograms of As/g tissue in roots and fronds respectively, when grown in such an environment.

PhD scholar Tracey Howkins and Professor Kerry Walsh at Central Queensland University have been studying this particular plant in collaboration with the National Research Centre for Environmental Toxicology (The University of Queensland – Queensland Health).

The AINSE supported component of this work has examined the localization of arsenic within the plant tissues, with an aim to developing an understanding of the physiological mechanism of arsenic tolerance and hyper-accumulation. A number of sample preparation methods was trialled, with tissue samples examined by light microscopy and scanning electron microscopy. Proton-induced X-ray emission (PIXE) was done together with Dr Rainer Siegle at ANSTO.

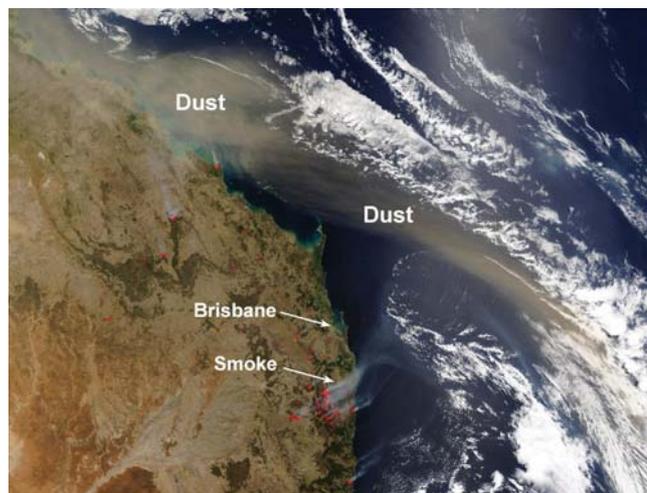


One of the samples of Pteris vittata used to demonstrate hyperaccumulation of arsenic

Australian dust deposition in the New Zealand: a proxy for inter-regional climate variability

Using the radiocarbon dating facilities at the ANSTO laboratories Dr Hamish McGowan and his student Samuel Marx from the University of Queensland have developed a multi-decadal record of trans-Tasman dust transport for the last 8000 years. Dust was extracted from an alpine mire in southern New Zealand and geochemically fingerprinted to specific source areas in New Zealand and Australia using a trace element mixing model. The model matches the chemistry of potential dust source areas such as Lake Eyre, with that of the deposited dust.

Changing dust source areas identified by the model and rates of dust deposition through time serve as a measure of environmental response to climate variability within dust source areas. Simply put, during dry climate phases dust transport in eastern Australia and its subsequent deposition at sites in New Zealand is high by comparison with more humid climate phases. Results from this study are being used to develop a better understanding of the impacts of climate variability in the Australian region. Importantly, they have shown that the Australian landscape responds quickly to climatic deterioration with significant increases in wind erosion and dust transport.



Satellite photograph showing dust and smoke plumes

Pearls of wisdom: pearl oyster shell documents contaminant history

Dr Geoff MacFarlane's team at the University of Newcastle has shown that pearl oysters are useful sentinels of the presence of environmental contaminants in estuaries. Pearl oysters have a higher filtration rate than most bivalve molluscs and thus can process up to 15 litres per hour of contaminated water. The filtration process can involve uptake of toxic chemicals by the oyster which can then either be broken down, or deposited into the shell matrix. Oysters can concentrate some toxic pollutants, especially toxic heavy metals, within their tissues and shell to much higher concentrations than surrounding waters. Perhaps the greatest advantage of pearl oysters as pollutant sentinels is the fact that the oyster simultaneously produces a marketable & extremely valuable product, the pearl, and the oyster is not necessarily bound for human consumption. These characteristics led our group to examine the biomonitoring potential of the Akoya pearl oyster *Pinctada imbricata*.

Each day pearl oysters deposit a layer of nacre, which is composed predominantly of aragonite or calcium carbonate, on the inner surface of the shell. MacFarlane thought that the heavy metal lead (Pb) may replace calcium in aragonite due to its similar ionic radius. Experiments were then devised where the oysters were either exposed to constant levels of Pb or two short term (pulse) exposures of Pb. Secondary ion mass spectrometry (SIMS) analyses of the nacre by Drs Rob Russell and Kathryn Prince at ANSTO, showed that Pb was accumulated in the successively deposited nacreous layers of the shell of *P imbricata*, documenting the exposure history of constant versus pulsed Pb events. Patterns of Pb deposition not only reflected the frequency of Pb exposure events but also accurately documented their relative duration. Thus, the shell of *P imbricata* may be employed as a suitable biological archive of Pb exposure history. Further AINSE funded research at ANSTO is examining whether these signatures may be detected under field conditions where oysters experience changes in metal pollutant exposures over time. This AINSE funded work has resulted in a publication in the International Journal Environmental Pollution.



Image courtesy of Department of Primary Industry, Fisheries

Aging a vegetation mosaic

A long history of Aboriginal landscape burning is thought to have maintained the fragmentary distribution of *Acacia aneura* shrublands within a matrix of *Triodia* grassland in central Australia. Managers are concerned that this mosaic is threatened by the breakdown of Aboriginal fire management following European colonisation. Professor David Bowman of Charles Darwin University tested this hypothesis on a near level sandsheet at the southern limit of the Tanami Desert in central Australia by (i) determining the chemical and carbon stable isotopic composition of 16 soil profiles across abrupt *Triodia* hummock grassland – *Acacia aneura* shrubland boundaries and (ii) soil chemical and physical characteristics of the two vegetation types. *Acacia aneura* has a C3 photosynthetic pathway while *Triodia* has a C4 photosynthetic pathway and hence these vegetation types leave distinct stable carbon isotope signatures. Accelerator Mass Spectrometry (AMS) ¹⁴C dating of 32 soil samples were done at ANSTO in collaboration with Dr Ugo Zoppi. This revealed that soil organic matter accumulated in profiles about 1m deep had a radiocarbon age of less than 2000 years. *Acacia* shrublands occurred on more clay rich soils with higher concentrations of total phosphorus, nitrogen and potassium than the surrounding grasslands. The observed patterns of soil nutrients and delta ¹³C were found to be consistent with only minor changes in the *A aneura* shrubland distribution over this time period. Nonetheless, field checking revealed numerous areas of *Acacia* shrubland that had been recently burnt or were regenerating following fire. In sum the shrubland – grassland mosaic appears to be stable at both the century and decadal scales despite (i) recurrent landscape fires and (ii) changes in fire management associated with the transition from Aboriginal to European land-use.

The mulga (*A aneura*) and spinifex (*Triodia*) mosaic appears to be less than one thousand years old. The mosaic was possibly established as a consequence of Aboriginal colonisation in the late-Pleistocene. The mosaics are maintained by an interaction between recurrent fires and the higher fertility in the mulga soils - burnt mulga can quickly re-establish itself because of the better soils.



Picture showing the two different landscapes: shrub and grassland

Research Highlights

Materials – Properties and Engineering

Better Rail Welds

Continuously welded rails have largely replaced mechanically-jointed track as the accepted method of joining rails. However, welding of rails introduces high levels of tensile residual stresses in the web region of the weld. Tensile stresses adversely affect the load carrying capacity of rail welds and promote the initiation and acceleration of crack growth from pre-existing defects under high axle loads. This condition presents a serious risk to catastrophic weld fracture which may cause trains to derail. Improvements to the service performance of rail welds may be achieved if localised tensile stresses in the weld region are reduced.

AINSE postgraduate scholar David Tawfik of Monash University studied the combined effect of welding and new *in situ* rapid post-weld heat treatments on residual stresses. Neutron diffraction was used to measure the residual stress distribution in the weld region of the rail. The results achieved by neutron diffraction revealed detailed insight into the magnitude and distribution of residual stresses in such welds. Neutron diffraction was also used as a bench mark to validate both finite element model and strain-gauge results for the first time. The combined effects of welding and rapid post-weld heat treatments significantly lowered tensile stress levels, and therefore reduced the risk of weld fatigue failure, thereby avoiding the risk of expensive train derailments.

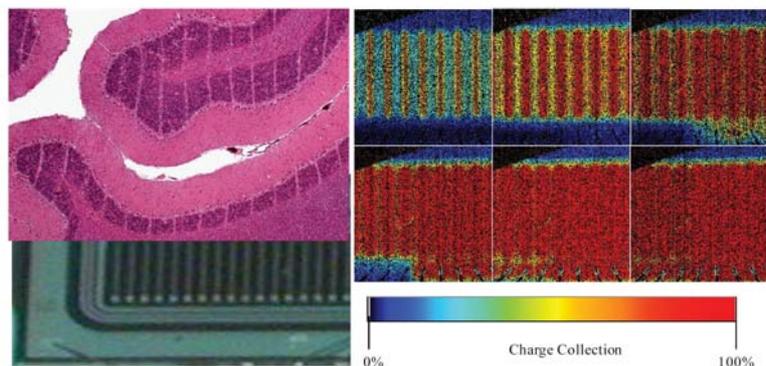


Close up of a rail which failed in the region of a weld

Monitoring a new treatment for inoperable tumours

Dr Michael Lerch and his team has developed new mini-strip silicon dosimeters at the Centre for Medical Radiation Physics, University of Wollongong for monitoring the instantaneous peak-to-valley dose ratio in microbeam radiation therapy (MRT) treatments. MRT is a new treatment which is being developed for previously untreatable and inoperable tumours. The aim of this project was to monitor the radiation damage of the new mini-strip dosimeters exposed to 60,000Gy from a synchrotron x-ray source with an MRT energy spectrum. Taking into account the low energy of the MRT x-ray beam, contribution to the bulk damage of silicon due to displacement defects was not expected. However, ionizing energy losses can be significant if damage of the passivated field oxide regions occurs.

The team was assisted by Dr Mark Reinhard, Dr Rainer Siegele and Dr David Cohen at ANSTO using the heavy ion microprobe to study the mechanism of charge collection using the ion beam induced charge collection (IBICC) method both prior and post irradiation at the medical beamline of the European Synchrotron Radiation Facility, France, where MRT is under development. Electrical characterisation experiments were also carried out at ANSTO to characterise and localise the radiation damage. The experiments showed that the new mini-strip dosimeters were of excellent quality and performed according to their design specifications. Both IBICC and electrical characterisation experiments indicated that the induced radiation damage was due to ionisation energy losses, localised to the silicon oxide layer of the detector. The results of this research will be taken into account in the next version of these detectors that will be manufactured in 2007.



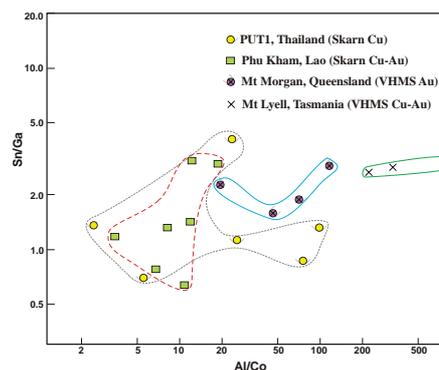
The new dosimeter dimensions (bottom left) will allow probing of the MRT beam (illustrated in the histopathological slide - top left). IBIC images (right) indicate the extent of radiation damage to the new dosimeter.

Trace element geochemistry of hydrothermal magnetites: PIXE/PIGE perspectives

Magnetite is a common iron oxide mineral found in many giant ore deposits such as Olympic Dam in South Australia and Cadia in NSW. However, chemical analyses of individual mineral grains are hampered by high detection limits in electron probe microanalysis. Use of techniques such as XRF or solution chemistry on mineral separates is associated with problems of contamination by foreign mineral inclusions.

Recent developments in micro-analytical techniques using non-destructive PIXE/PIGE at ANSTO combined with destructive LA ICP-MS analysis at CODES ARC Centre of Excellence in Ore Deposits, University of Tasmania were used by Dr Khin Zaw of the University of Tasmania to generate magnetite compositional data with three goals in mind: first, to understand magnetite formation and how trace elements are incorporated into magnetite; second, to characterise magnetite and the associated deposits and third, to refine or formulate ore genesis and exploration models.

For example, the scatter plot of Al/Co against Sn/Ga by PIXE analyses shows that magnetite samples from the Cu and Cu-Au skarn deposits from Thailand and Laos have a broadly similar Sn/Ga ratio to those from Mt Morgan (Au) and Mt Lyell (Cu-Au) VHMS systems, suggesting a commonality of magmatic affinity.



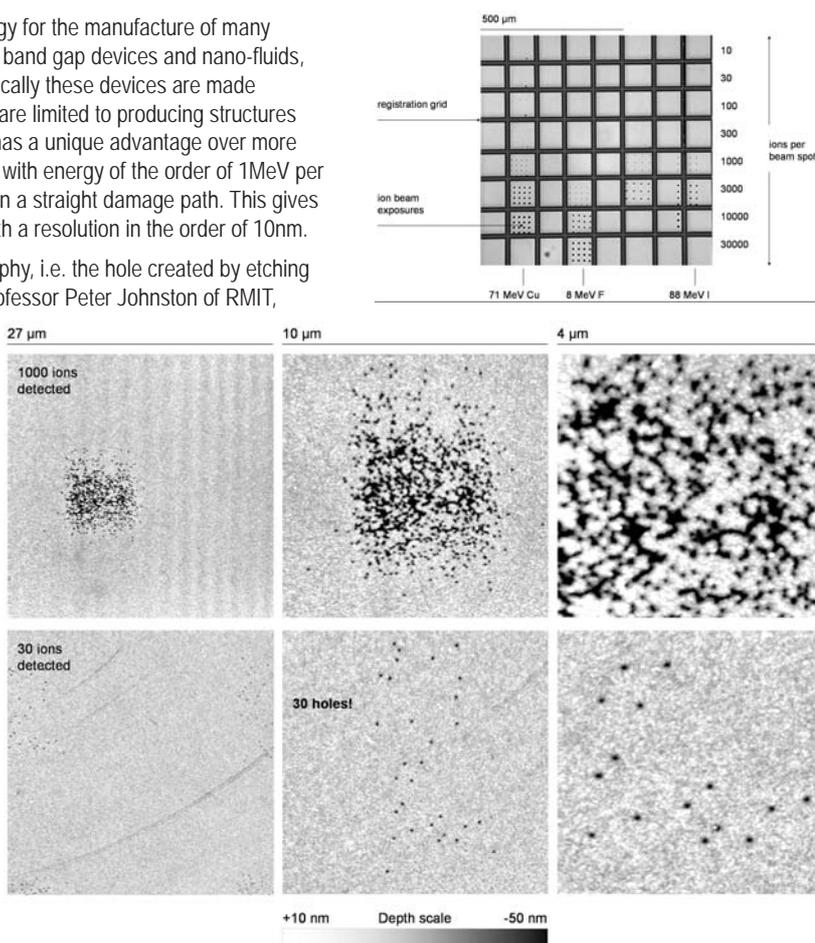
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A better way of making nano-sized holes

Lithography on the nanometre scale is a key technology for the manufacture of many modern devices including integrated circuits, photonic band gap devices and nano-fluids, and example is shown in the diagram to the right. Typically these devices are made using electron beam, optical or UV lithography, which are limited to producing structures with small aspect ratios. Ion Beam Lithography (IBL) has a unique advantage over more traditional electron beam or optical lithography. An ion with energy of the order of 1MeV per nucleon evenly deposits its energy over a long range in a straight damage path. This gives IBL the ability to create high aspect ratio structures with a resolution in the order of 10nm.

In order to study the ultimate limit of ion beam lithography, i.e. the hole created by etching away the damaged region along a single ion track, Professor Peter Johnston of RMIT, together with Dr Rainer Siegele at ANSTO, has used a novel experimental procedure. A common photo-resist (PMMA) was used to spin-coat the top of a photodiode substrate. The photodiode is a functioning ion detector which enables control over the exact number of ions delivered to an area defined by the ANTARES ion microprobe beam spot. The fluence inside individual beam spots was adjusted so that separated single ion tracks were created without overlap. Three different ion species, 8MeV fluorine, 71MeV copper and 88MeV iodine, were investigated so that the formation of the holes could be studied as a function of the ion's Linear Energy Transfer (LET). The use of the heavy ion microprobe was crucial in obtaining precise control over beam positioning whilst being able to experiment over a large range of LET values. This results in holes approximately 30nm wide.

Ion beam nanolithography may allow the manufacture of nanometre scale devices with much greater 3D structure offering new possibilities in integrated circuits, nano-fluidics and devices such as lab-on-a-chip.



Electron micrograph images showing single ion holes

Research Highlights

Materials – Structures and Dynamics

As recorded in the President's report AINSE introduced a new program in 2006 – the Research Fellowship. Both fellows will work in the specialist area of Materials – Structures and Dynamics.

The research fellowships are tenure track and are for a maximum of five years. Entry level is at lecturer B and AINSE offers a generous equipment and travel supplement to help the fellows establish themselves. AINSE intends to offer two new fellowships each year for people with three to eight years postdoctoral experience in neutron science.

As it turns out both were research students who benefited from AINSE support during their postgraduate research. Dr Goossens was not only an AINSE postgraduate scholar but he also took out the Gold Medal for excellence in research in 1999.

Dr Riley studied with Professor Erich Kisi at the University of Newcastle before taking up his research fellowship at the University of Melbourne.

The two pieces on this page profile these new research fellows and provide a snap shot of their research interests and their plans.

Pain killers at the molecular level

AINSE research fellow Dr Darren Goossens has been studying short-range order in molecular systems. He has focused on two systems: Ibuprofen, a common pain killer (figure 1), and paraterphenyl. These two systems have been explored using x-ray and neutron diffuse scattering in order to look at how molecules interact in the crystalline state. In Ibuprofen, the key intermolecular interactions were identified and aspects of the molecule's conformation space were mapped out. In paraterphenyl, the incipient superlattice peaks were identified and related to the interactions dominating the critical behaviour. The 'average' position of the atoms, as revealed by conventional studies, is often not enough to explain the interesting properties. But 'getting inside' this average is difficult. It requires new experimental techniques to be developed and new data analysis techniques to be used. Once you have these techniques, you can use them to explore how a material behaves close to a phase transition – known as its critical behaviour. (For example, some materials will change their atomic arrangement as they are heated up or cooled down; in doing so they go through a phase transition.) You can also look at how molecules interact with each other inside a crystal, and what small-scale groupings of atoms combine to give the averages observed in conventional experiments.

Oxide ferroelectrics: how do they work?

Dr Darren Goossens has also been investigating the relaxor ferroelectric PZN, $\text{PbZn}_{1/3}\text{Nb}_{2/3}\text{O}_3$ using neutron diffuse scattering in order to reveal the nanodomain structure. He found that the domains lie in planes perpendicular to $\langle 110 \rangle$ directions and consist of Pb atoms whose displacements from the average position at the centre of their polyhedron lies in a $\langle 110 \rangle$ direction within the plane of the domain as shown in the figure to the right.

In 2007 and onwards his intention is to continue to improve the ability to analyse diffuse scattering data, and apply these ever-improving techniques to key problems in materials science.

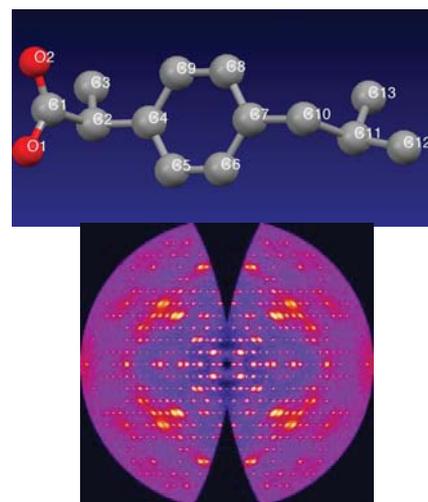


Figure 1: A molecule of ibuprofen, top, and the observed diffuse scattering in the $hk0$ plane, measured at the Advanced Photon Source

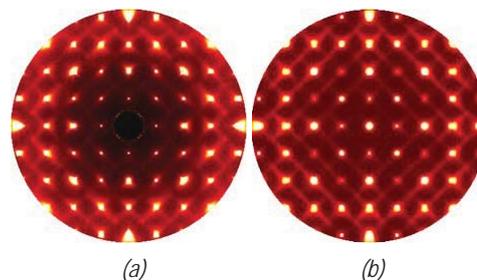


Figure 2: (a) The $hk0$ plane of neutron diffuse scattering from PZN, measured on SXD at ISIS. (b) The same plane calculated from a model with a domain structure like that seen below.

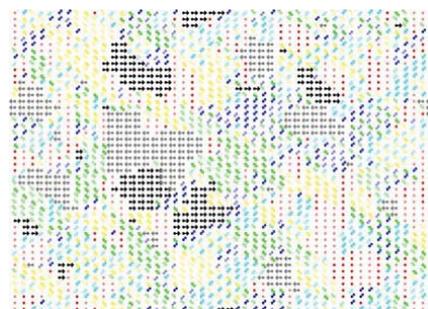


Diagram showing planar alignment of lead atoms in the relaxor ferroelectric PZN, $\text{PbZn}_{1/3}\text{Nb}_{2/3}\text{O}_3$

Applications of high intensity neutron diffraction

The past decade has seen an important evolution in the designs of high intensity powder diffractometers (HIPD), e.g. D20 (Institut Laue-Langevin, France) and GEM (ISIS, UK). Within the next year, Australia will for the first time operate similar facilities, with the commissioning of the WOMBAT-HIPD at the OPAL Research Reactor (ANSTO, Lucas Heights, Sydney). Central to the operation of HIPDs are novel position sensitive detectors (PSD), capable of intersecting significant proportions of the diffracted intensities and thereby reducing the acquisition time for each pattern (<1s/acq.). Suitable for application on reactor or spallation sources, these new generation HIPDs are finding increasing application in the study of time-resolved reactions. Combined with the high transmission efficiency of moderated neutrons and the unique scattering lengths of each element, neutron HIPDs can accurately determine the reaction kinetics of industrially relevant processes when combined with quantitative phase analysis (QPA).

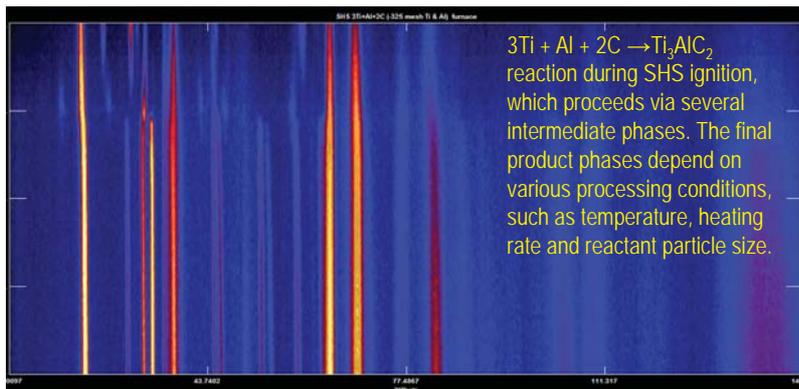


Figure 2 – Time-resolved neutron diffraction of the ignition mechanism during self-propagating high-temperature synthesis (SHS) of titanium aluminium carbide (Ti₃AlC₂).

AINSE research fellow Dr Daniel Riley and A/Professor Erich Kisi of the University of Newcastle have been using high intensity neutron diffraction to investigate ultra-fast reactions during self-propagating high-temperature synthesis (SHS). Utilising the exothermic heat of formation to sustain a self-propagating reaction, SHS has proven an efficient technique for synthesizing a novel class of materials, MAX Phases, which combine a unique combination of ceramic and metallic properties. Figure 1 provides detail of the lamellar structure of titanium silicon carbide (Ti₃SiC₂), which is the key to understanding many of these unique physical properties. This technique has recently been applied to the reaction mechanism responsible for initiating SHS reactions (i.e. SHS ignition). Figure 2 is an illustrative data set obtained during the SHS reaction, 3Ti + Al + 2C → Ti₃AlC₂. With diffraction angle (2°) on the x-axis and time on the y-axis, Rietveld analysis of this data has shown that the reaction mechanism proceeds via several intermediate phases, resulting from solid-state inter-diffusion of reactants. Importantly, it was resolved that the structure of these intermediate phases can directly influence the reaction efficiency, with retention of secondary phases if processing conditions are not optimal. HIPD has proven to be a useful tool in determining these optimal conditions.

Towards a better understanding of biomaterials

In her PhD research, AINSE postgraduate scholar Lisa Rodgers used neutron scattering and complementary analysis methods to examine the structure of sol-gel biomaterials. Sol-gel immobilisation had previously been shown to enhance the activity of some lipases, although the mechanism for this was unclear. An industrial lipase, *Candida antarctica* lipase B (CALB), commonly used in organic synthesis reactions, was chosen for encapsulation experiments.

Small angle neutron scattering (SANS) studies showed that the contrast match point for the sol-gel matrix, both with and without the enzyme present, was lower than predicted. The contrast match point of the protein should be moved through *in vivo* protein deuteration in future experiments of this type. Experiments utilising NMR, activity studies, light scattering and nitrogen sorption allowed better understanding of the interactions between the CALB and the sol-gel material throughout the gelation process. It was shown that the enzyme influenced sol-gel structure by altering silica speciation and porosity. Correlation of activity data to these changes showed that the enzyme's catalytic activity was potentially involved in sol-gel gelation reactions and the structure of the resulting biomaterial.

This project advanced the understanding of interactions between sol-gel matrices and a model encapsulated enzyme. Many of the insights gained in this work may be applied in the future characterisation of complex biomaterials.

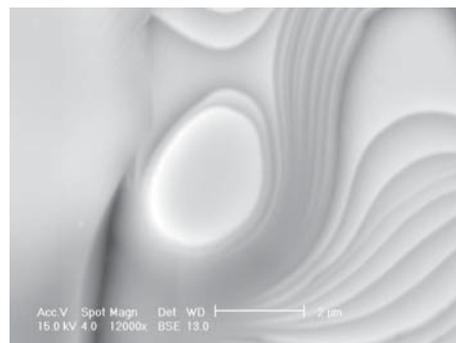
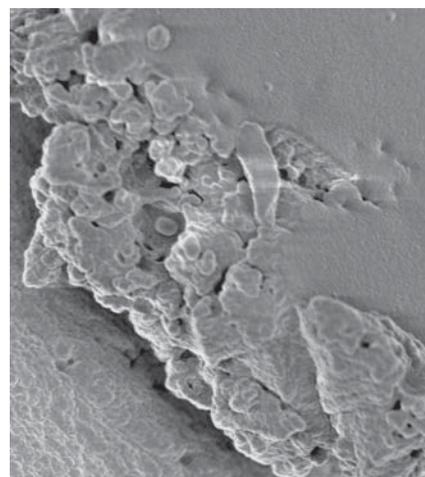


Figure 1 – Scanning electron microscopy (SEM) image of the layered morphology of Ti₃SiC₂.



Electron micrograph of *Candida antarctica* lipase B enzyme

AINSE Winter School 2006

Saturday 1st to Wednesday 5th July 2006

The School continues to be a most valuable AINSE activity for the promotion of research opportunities at ANSTO to prospective research students. One student is selected by the AINSE councillor at each of the 39 member universities.

The program is interdisciplinary and although it is clear from some comments that some students feel challenged at being taken out of their physics or chemistry comfort zone, the variety of experiences, both in the formal classes and through working with other students is an important part of the School experience.

The topic on radiation safety (ANSTO Safety and Radiation Services) introduced in 2005 was expanded to include an exercise in spill detection and decontamination. In the topic on nuclear techniques in environmental studies a potentially interesting development was marred by instrumental problems – a useful reminder to the students that using leading edge instruments is not without problems.

The AINSE Postgraduate Scholars, Geoff Johnston-Hall (QLD), Kat Lilly (ANU), Leigh Sheppard (NSW), Mark Callaghan (UTS) and Susan Pearce (ADE), made a very important contribution to the School as demonstrators, role models and through the presentations on their research. They are warmly welcomed by the students and the Winter School and AINSE are very grateful for their commitment to the School.

Students

Details of the students and their broad disciplines are given on the next page. The total number of disciplines exceeds 39 because 7 students were doing a double discipline major and each of these has been tallied. Chemistry and Physics dominated the School this year. Like last year, student numbers in environmental areas slightly exceeded those in engineering. The gender ratio was 14 females to 25 males.



Winter School 2006, entire group

This year the following students attended:

Name	Uni	Name	Uni	Name	Uni
Michael Barnett	UTS	Ben Fulcher	SYD	Grant Mockunas	BAL
Rachael Barnett	JAM	James Gill	TAS	Zoe Moffat	OTA
Christopher Beer	SWI	Kate Grant	VIC	Nicola Moody	ACU
Byron Booth	GRI	Mitchell Holmes	CSU	Brad Murnane	MON
Jocelyn Bouzaid	QUT	Gillian Hunt	MAC	Shaun Nichols	CBR
James Brugler	MEL	Angela Hurley	WOL	Nathan O'Dea	NSW
Nathan Cooling	NCT	Elaine Jee	CUR	Daniel Packwood	CAN
Andrew Cottrill	USQ	Anwen Krause-Heuer	UWS	Trent Pohlmann	CQU
Grant Dawson	QLD	Finnian Lattimore	ANU	Tyler Raeside	FLI
Christopher Doropoulos	ECU	Lisa Matson	SCU	Hailey Reynolds	RMI
Rhys Dowler	AKL	David Mavros	USA	Sarah Samulkiewicz	MUR
Philip Downing	LAT	Peter Medley	CDU	Kieran Stockton	UNE
Laura Erikson	DEA	Richard Meyer	ADE	Gar Wing Truong	UWA



Dr Andrew Smith explaining the workings of the ANTARES accelerator

Discipline	No
Chemistry	15
Physics	10
Biology	1
Environment	6
Earth Sciences	2
Engineering	4
Medical Sciences	1
Sum	39

Special Speakers

Professor Mark Tester of the Centre for Plant Genomics, University of Adelaide, spoke on the lessons for all scientists in the discussions on GM crops and risk perception in evaluating GM materials and foodstuffs; and AINSE President Professor John White spoke on energy and nuclear options. Both presentations were received with enthusiasm and lively debate which spilled over into the discussion session on Tuesday night on ethics in science.

Thanks

The Convenor of the Winter School and Scientific Secretary of AINSE record their gratitude and that of the students to the Board, the Executive Director and the staff of ANSTO for their generous contribution to the School. They thank all the ANSTO staff who gave so much of their time and talents in making the School a success.

2006 Conferences & Workshops

AINSE conferences play a major part in the information exchange process for scientific and technological information, providing a forum for debate and an opportunity for young researchers to present their work. Participants from member organisations are assisted with travel and accommodation expenses and receive a discount on registration fees.

AINSE ran five national conferences in 2006. Two of the national conferences were part of the AIP National Congress.

Radiation Conference

20 - 21 April, The University of Sydney

There were 68 participants at the AINSE Radiation Science Conference (incorporating the 21st AINSE Radiation Chemistry and the 18th Radiation Biology Conference). Of the 68 participants, 6 from ANSTO, 3 from overseas and 27 were students; 63 papers and 22 posters were presented.

AINSE is grateful to the RACI Polymer Division for providing invaluable support for this conference.

5th AINSE/ANBUG Neutron Scattering Symposium

11 - 13 December 2006, Sydney

The AINSE/ANBUG (Australian Neutron Beam User Group) Neutron Scattering Symposium was held at AINSE. There were 79 participants including 28 from ANSTO, 4 from overseas and 15 students, 59 papers and 30 posters were presented.

21st Nuclear and Particle Physics Conference held in conjunction with The Australian Institute of Physics 16th Biennial Congress 2005

3 - 8 December 2006, Brisbane Convention Centre

Of the 44 abstracts accepted 21 were oral presentations.

The balance between presentations was approximately 50% Particle Physics/Fundamental Interactions and 50% Nuclear/Applied Nuclear. Ten of the oral presentations for AINSE-NUPP were given by women including Helen Quinn, from the Stanford Linear Accelerator Center, who presented a talk on theoretical particle physics. Three AIP awardees were included in the sub-sessions: George Dracoulis, (Boas Medal), James Tickner (Walsh Medal together with Dr Brian Sowerby) and Mahananda Dasgupta (Women in Physics Lecturer). Keynote talks were selected to represent activity across the field: Phil Urquijo and Tom Atkinson from The University of Melbourne, Hugo Maier from Berlin/ANU, Derek Leinweber from University of Adelaide, David Hinde from ANU and Victor Flambaum from UNSW.

The AINSE-NUPP meeting had a ratio of oral presentations to submission of 0.47 compared to that for the whole Congress of 0.31. This decision resulted in 21 slots being allocated to the AINSE-NUPP meeting. The AINSE-NUPP committee chose to give preference to students and young researchers for oral presentations over more senior staff members. This decision was vindicated by the very high standard of presentation of most of the talks. The Congress organization ensured that the poster presentations were well attended and this aspect was also highly successful.

26th Plasma Science Conference held in conjunction with The Australian Institute of Physics 16th Biennial Congress

3 - 8 December 2006, Brisbane Convention Centre

The plasma community were allocated 10 slots for oral papers. Another 16 papers were presented as posters. A highlight of the plasma sessions was the presentation by Professor R Goldston from Princeton Plasma Physics Laboratory who gave an impressive overview of progress in the understanding of tokamak physics on the path to controlled fusion. Travel bursaries were provided to assist travel expenses for 14 students from 10 universities who attended this meeting.

Australian ITER Forum Workshop

11-13 October, Manly Australia

The Australian ITER (International Thermonuclear Experimental Reactor experiment) Forum Workshop was attended by 82 people including 12 representatives of the ITER partners, 7 from industry, 3 from the Australian government, 5 from ANSTO and 16 students; 23 papers were presented. It was opened by the Chief Scientist Dr Jim Peacock.

Six student bursaries were provided to undergraduate students who are considering further studies in this area.

AINSE is grateful for the support of the International Science Linkages Fund for financial support for this workshop.

AINSE acknowledges the support of H1-MNRF, The University of Newcastle, The University of Sydney, COSNET, Murdoch University and the University of Wollongong



ITER Forum Workshop participants

International Conference Travel Scholarships

These scholarships are available to students and post doctoral fellows from AINSE member universities who wish to present their AINSE supported research at an international meeting which is being conducted outside Australia. Nine International Travel Scholarships were awarded during the year to the following students:

Cameron Barr from The University of Adelaide, Joanne Muller from James Cook University, John Daniels, Adam Fischmann and Anna Paradowska from Monash University, Manickam Minakshi from Murdoch University, Catherine Kealley from The University of Technology Sydney, Mark Waller from The University of Sydney, and Craig Sloss from Wollongong University.

For more information about International Travel Scholarships see our web site