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President's Report

The Australian Institute of Nuclear Science and Engineering (AINSE) is a partnership between Australian Universities and the Australian Nuclear Technology Organisation (ANSTO). It provides research grants to support projects requiring access to the facilities at ANSTO and other AINSE associated facilities. AINSE also provides support for Postgraduate students in the form of Postgraduate Research Awards and facilitates collaborations between university researchers and ANSTO scientists and technical personnel. Pier review of applications for research grants is provided through its 5 specialist review committees.

The AINSE collaborations at ANSTO have produced more than 200 PhD theses and have produced an average of 230 research publications per annum; this year we record 257 publications in referred journals. There are currently some 400 University researchers who are active project award holders.

AINSE was founded in 1958 with an initial membership of eight universities and ANSTO and has now grown to include 37 Australian university members as well three New Zealand institutional members.

AINSE also organises national conferences and assists Australian institutions in organising International Congresses. In addition, AINSE continues to run the highly successful AINSE Winter School for senior undergraduate students.

A major event in the past year was the completion and commissioning of the new accelerator (STAR). It is now fully operational and was officially "opened" by the Honourable Dr Brendan Nelson, MP, Minister for Education, Science and Training in January 2005. The STAR accelerator was purchased by AINSE with financial assistance of an ARC LIEF grant and major contributions from ANSTO and 27 universities.

A major application of the STAR accelerator will be for carbon-14 accelerator mass spectrometry for sample dating as well as analysis using ion beam analysis techniques. AINSE also purchased an automatic element analyser, isotope ratio mass spectrometer and sample preparation system. This facility speeds up sample preparation and will substantially increase sample throughput on the new accelerator.

The construction of the replacement research reactor, now known as "OPAL" is proceeding well and this facility will provide a world-class neutron source that will greatly enhance the research capability for AINSE supported projects. ANSTO, in consultation with AINSE is in the process of designing the access program for researchers to the new OPAL facilities and beam lines.

ANSTO is also constructing a neutron reflectometer that will be of great interest to researchers working on molecular films, colloids and surface structures. This instrument will be used with the current reactor (HIFAR) before being transferred to the new facilities on OPAL.

AINSE researchers have also continued to bid successfully for time on the neutron spallation source (pulsed neutron source - ISIS) in Oxford (UK). Access is determined by peer review of the projects and the subscription for access is underwritten by AINSE and an ARC LIEF grant to AINSE.

AINSE is now actively implementing its Strategic Plan developed and adopted by the AINSE Council during 2003-2004. Details of this strategic plan can be found on the AINSE Web site. The plan provides for a wider scope of membership of AINSE by research institutions as well as enabling the inclusion of additional research facilities to come under the AINSE umbrella. This will allow the highly successful AINSE model to be extended into new areas and provide a link between researchers and institutions using nuclear techniques and instrumentation in a wide range of disciplines.

AINSE has always, from the outset, strived to promote excellence in research and this continues to be the primary driver for projects that are supported. The new strategic plan also will put into place key indicators to better monitor research outcomes and set targets for growth in the quantity and quality of AINSE supported research programs in the future.

In line with the Strategic plan and following representations made to some universities in New Zealand, I am pleased to report that AINSE has now has three New Zealand institutions as members. AINSE will continue to encourage other universities in New Zealand to join AINSE.

During the past year I was most pleased to welcome Dr Ian Smith, the new CEO of ANSTO, to the AINSE Executive. Dr Smith is not a newcomer to AINSE having been an AINSE supported postgraduate student. Prior to Dr Smith's appointment to ANSTO, Dr George Collins represented the ANSTO CEO on the AINSE Executive and I would like to thank him for his valuable contributions and incisive input to the Executive deliberations. It was pleasing to have Professor Allan Chivas join the Executive for 2005.

As President of AINSE for the last two years it has been very satisfying to have had the opportunity to lead the lively and cooperative research community that is AINSE and be part of the advancements that AINSE has made. I would like to thank the members of the Executive and the Councillors for their valuable input and collegiate support. With the new OPAL facilities coming on-line in the near future and with new plans taking shape on university funding by the Federal government, the future for AINSE should prove interesting for Professor John White who is taking over the reigns.

Professor Hans G L Coster

President, 2003-2005

clockwise from left: The Honourable Danna Vale MP, The Honourable Dr Brendan Nelson MP, Professor Ann Henderson Sellers, Professor John White, Professor Hans Coster, Dr Rob Robinson, Dr Dennis Mather at the STAR launch

The Honourable Dr Brendan Nelson MP, unveiling the STAR plaque with in coming AINSE President Professor John White

Scientific Secretary's Report

During 2004 the rate of change in the research and education environments has continued to drive AINSE forward. We completed our first benchmarking document which focussed on neutron scattering and now we will move to benchmarking other areas of activity.

AINSE Council meeting in December was a great success, thanks to RMIT University and councillor Professor Peter Johnston, and Professor Jim Camakaris and Honorary Fellow Dr Ron Cooper.

AINSE provided continuing support for neutron scattering workshops organised by the Bragg Institute, in addition to running the 4th Symposium on Neutron Scattering in December.

The introduction of the International Travel Scholarship to assist students and post doctoral fellows to present their work at international meetings had a soft launch in November with two students receiving support to attend a conference in Rome.

AINSE Postgraduate Scholar Andrew Wroe distinguished himself early in 2004 by winning a three month International Atomic Energy Association appointment as well as a Fulbright Scholarship to work at Loma Linda University in 2005.

With considerable sadness I record that two stalwarts of AINSE passed away in 2004: Professor Brian Spicer AINSE President from 1987 to 1988 and joined AINSE as Councillor for the University of Melbourne in 1974 passed away in August; and Professor David Allen-Williams, Councillor for University of Western Australia from the beginning in 1958 until 1983 passed away in July.

Council and Committees

Two thousand and four was the final year for Professor Hans Coster's Presidency. The Executive Committee acknowledged a number of initiatives commenced by Hans extending an invitation for him to continue his tenure on the Executive Committee for another year, as Immediate Past President, to complete these. The most significant being the extension of membership to more New Zealand Universities. I am pleased to report that a request for membership was received from the University of Canterbury in December.

On AINSE Council the following changes occurred during 2004.

ANSTO's Professor Helen Garnett, Dr Stuart Carr, Jack Dillich, replaced by Dr Ian Smith, Dr Ron Cameron, and Dr George Collins

University of New South Wales's Professor Hans Coster replaced by Professor Robert Burford

Flinders University's Professor Peter Teubner replaced by Associate Professor Michael Brunger

La Trobe University's Professor Paul Pigram replaced by Dr John Webb

University of Canberra's Professor Mohamed Khadra replaced by Professor Andrew Cheetham

University of Southern Queensland's Professor Malcolm McKay replaced by Professor Graham Baker

The Institute of Geological and Nuclear Science joined as a full member and is represented by Dr Frank Bruhn

AINSE is grateful for the dedication and generosity of all those who contributed to the various committees and Council. Without their input the organisation would not be able to move forward with such surety.

The commitment to refresh membership of the specialist committees has resulted in many changes on these committees, see page 4 of Section 2 of this report.

Finances

In 2004, income of $2,806,810 was made up of $1,464,853 from ANSTO's membership fee, $768,845 from universities, $391,250 from external grants, $165,261 from interest, and $16,601 from other sources. Membership subscriptions are reviewed annually to determine AINSE support for each university. On average, for the period 2000 to 2004 inclusive, universities received research and training benefits amounting to 3.13 times their subscriptions.

AINSE's operating expenses in 2004 were $2,845,820, leaving a deficit for the year of $39,011, see figure 2, this was less than the plan. The majority of AINSE funds are used to facilitate travel and access to Lucas Heights for university researchers and their research students and while the initial budget for 2004 Awards was $1,500,000 uptake was $1,447,293. While this is below the budget it is significantly more than that last year. Expenditure would have been higher but for the change over from the old 3MV van der Graaff to the new Tandetron which was commissioned in the middle of the year but still needed significant time to ensure that it is providing reproducable results. There was slightly over budget expenditure on Postgraduate Awards due largely to a greatly increased number of new Awards.

The 'Other Expenses' category is largely comprised of conference management expenses.

The Financial Statements for the calendar year 2004 are in section 2 of this report starting on page 6 and were prepared by ANSTO Finance and audited by Escott Aston and Co.

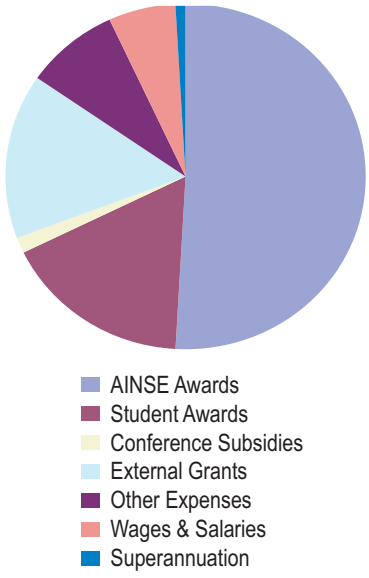


Figure 1 Operating Revenue

Awards and postgraduate research awards

A total of 168 Awards were made in 2004 and another 104 were carried over from previous years. Figure 3 shows the distribution of 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 168 Awards 127, or 76% were in collaboration with ANSTO. First time award holders in 2004 represented 24 per cent of the cohort, which is slightly lower than last year's figure of 25 per cent. I attribute this continuing high influx, in part, to the diligence of our Councillors and to my university visit program; in 2004 I spoke with researchers and students at 25 members campuses. My thanks go to the Councillors without whom these visits would be much more difficult to organise and not nearly as effective.

In 2004, 21 of the 52 AINSE postgraduate research award holders received an award for the first time. During the year fourteen PhD theses were received. The AINSE postgraduate research award holders accessed the facilities for a total of 1544 days. In addition, another 91 students gained access to the facilities via awards held by their supervisors for a total of 787 days.

This year we record 454 publications of which 251 are in refereed journals. Details can be found in section 2 of this report.

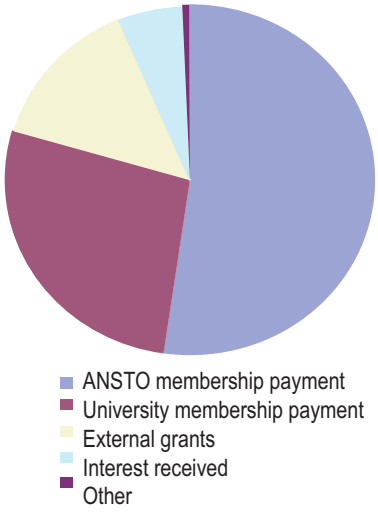


Figure 2 Operating Expenses

Acknowledgements

In his second year as President, Professor Hans Coster has continued to provided me with invaluable advice and strong support throughout the year. The visits we made to universities and other organisations in New Zealand were particularly interesting and beneficial.

I thank Dr Ian Smith who immediately demonstrated support for AINSE and has followed through with regular participation in Executive and Council meetings. Ian was once an AINSE Postgraduate Scholar and I look forward to a future interaction between AINSE and ANSTO which will extend the reach of both organisations. 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 Ben Thompson, Kylie Miles, Nerissa Phillips and Sandy O'Connor have continued to work hard and maintain the long standing reputation of a friendly and cooperative secretariat.

Finally, a special thanks to Peter Thompson who negotiated the final wording with the research highlights contributors and compiled both sections of this report.

Dennis Mather
Scientific Secretary

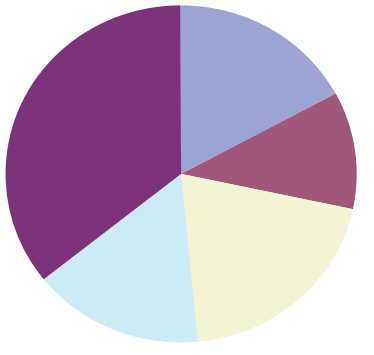


Figure 3 Expenditure by Specialist Area

Research Highlights

Archaeology and Geosciences

2000 years of drought history

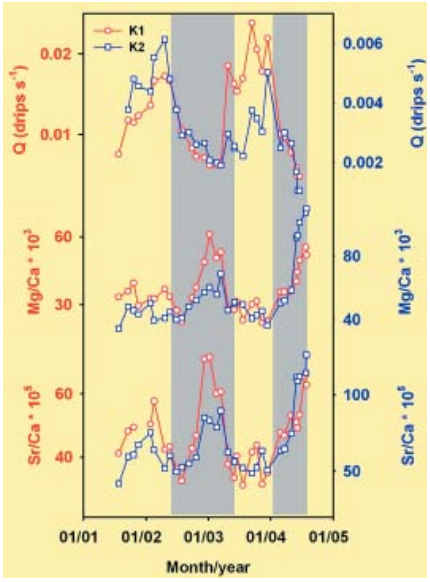
The 2002 - 2003 El Niño brought one of the most severe droughts on record to eastern Australia. The reasons why drought severity in Australia is so geographically variable are poorly understood. A valuable perspective could be gained if the latest drought could be compared with others over a long period. Instrumental climate records only provide data back to the mid-1800s. Pre-instrumental time periods can be studied using geochemical variations in natural archives that are sensitive to drought, such as cave stalagmites.

A 36-month study of drip hydrochemistry from Kooringa Cave, eastern NSW, by AINSE Postgraduate Award scholar Janece McDonald and Dr Russell Drysdale of the University of Newcastle and David Hill at ANSTO revealed a clear trace-element geochemical response to the 2002 - 2003 El Niño.

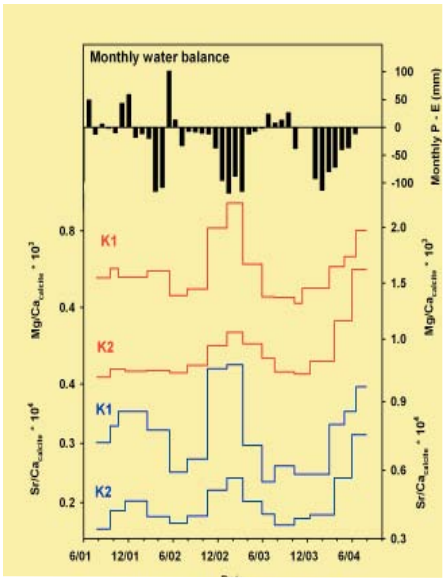
Major cation analysis using an inductively coupled plasma – atomic emission spectrometer at ANSTO revealed that the trace element ratios of magnesium to calcium and strontium to calcium display a marked increase during both the 2002-2003 drought and a second drought in the first half of 2004.

Because stalagmite calcite geochemistry is dependent upon that of the drip water, these results indicate that stalagmites from shallow caves in drought-sensitive eastern Australia potentially preserve a valuable record of El Niño-La Niña history. A 2000-year drought-history reconstruction from two such stalagmites is now under way.

Drip monitoring site at Kooringa Cave, Wombeyan, NSW



Drip discharge and ion ratio trends during the 2002-3 El Niño and 2004 drought (grey panels). K1 and K2 are the two drip sites.



Predicted calcite values for the same period.

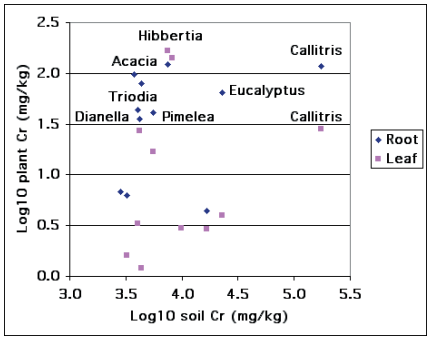
Heavy metal munching plants!

Phytoremediation of low-level contaminated sites is an inexpensive and environmentally friendly alternative to conventional capping or dig-and-haul remediation works. Ideally, phytoremediators should be able to extract heavy metals while providing habitat and enhancing local ecosystems.

Dr Damian Gore, Maria de la Torre and Barbara Rice from Macquarie University and Helen Waldron from Becquerel Laboratories have been using Instrumental Neutron Activation Analysis (INAA) to audit plants growing naturally on high-chromium (Cr) serpentinite substrates in the New England Fold Belt.

Cr is of interest because it has been used in cooling towers as a rust and corrosion inhibitor and as a fungicide. It is still used in pigments, metal finishing and electroplating, as well as in wood preservatives and leather tanning.

Few plants extract Cr but Dr Gore and his team have been able to find a number of plants that accumulate Cr, including what is potentially the first Cr hyperaccumulator identified with concentrations well in excess of 1,000 mg/kg, see diagram at the top right. However, this hyperaccumulator and its root system are small, limiting its usefulness for phytoremediation. Other fast growing species with up to 400 mg/kg Cr in their shoots show promise for commercial application. If successful, the Australian community will benefit from the availability of low cost, environmentally friendly options for remediating Cr contaminated soils.



Above: soil Cr versus plant Cr. Plant parts with Cr concentrations ≥ log2.0 mg/kg are of particular interest for phytoremediation applications.

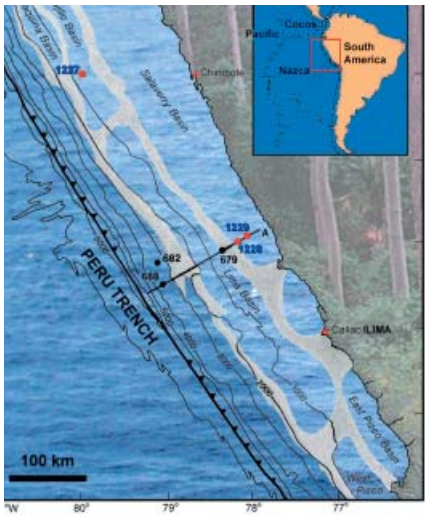
The photo to the left shows open eucalyptus woodland at Woodsreef mine, NSW. Rare plants exist among the grasstree and spinifex tussock flora at this site. Black chromite ore piles are visible in the distance.

Additional El Niño cycles

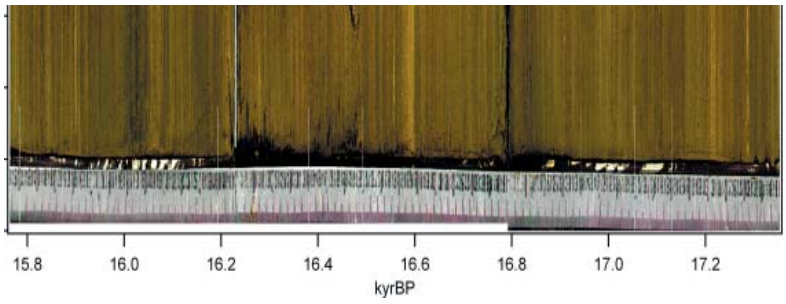
Apart from being the home of the El Niño phenomenon, the continental shelf off Peru contains an archive of laminated sediments extending back for at least 20,000 years before present (BP) and giving a time resolution to periods of less than 10 years.

Three cores collected during an Ocean Drilling program in 2002 have been studied by a group comprising Professor Greg Skilbeck and honours student Michael Watson of the University of Technology, Sydney, Dr Mike Gagan of the Australian National University, Dr Ian Goodwin of the University of Newcastle and Dr David Fink at ANSTO. Accelerator Mass Spectrometry (AMS) dating of the Holocene and early post-glacial sections of these cores has allowed resolution of sedimentation events on a scale of the same order as El Niño base variability (i.e. sub-decadal). Analysis has confirmed an El Niño origin for the layers, with darker, thicker bands representing increased terrestrial sediment supply and generally warmer sea surface temperatures associated with El Niño events in the eastern Pacific Ocean.

Time series analysis has shown important long-term cyclicity in El Niño during this time. Apart from the interannual variability in the range of 2-7 years, analysis has revealed strong cycles at 11 and 22 years, and at 150 years. Early indications are that there might be a link between the variation in solar radiation output (sun spot cycles) and the duration and intensity of El Niños, at least as the Earth was emerging from the last ice age.



Map of the Peru margin showing the location of the three cores available for this study. Coring sites are located in small sub-basins on the shelf which allow for accumulation of sediments in areas of anoxic bottom waters.



High-resolution scanner image of sediment from the Peru continental margin. Laminations represent interannual climate variability with the darker bands reflecting higher terrigenous sediment input and warmer surface waters during El Niño events.

Research Highlights

Biomedical Science and Biotechnology

Low dose ionising radiation

Ionising radiation can cause chromosomal changes which are part of the process of the development of cancer. It is important for us to have radiation standards which lay out levels of exposure for various types of exposure which are considered to be safe. These standards are presently determined based on the linear no threshold (LNT) dose response model. This model predicts that the relationship between biological effects such as chromosomal changes and radiation dose is linear, and that even the tiniest dose will have a damaging effect. Almost all of the data on biological effects of ionising radiation come from the study of high doses. The human population is, however, unlikely to be exposed to such doses.

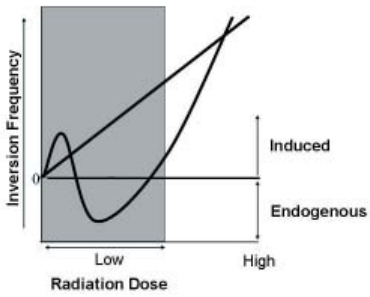
Researchers Associate Professor Pamela Sykes and Dr Antony Hooker from Flinders University and Medical Centre have developed a sensitive mouse assay which enables observation of chromosomal inversion (a common type of chromosomal change observed in many cancers) in mouse tissues at doses of radiation that are 1000 times lower than anyone else has reported.

Their results suggest that ultra-low doses of radiation (5-10μGy) cause more inversions than low doses (1 – 10 mGy). In fact, at low doses the number of inversions is less than in unirradiated animals suggesting a possible protective effect. Further studies on the biological mechanisms involved need to be performed in order to understand if the effect is truly protective.

These results do not fit a LNT model, and may have implications for the way in which regulatory standards are presently set and for understanding radiation effects. These data have been determined using single, high dose-rate exposure which is relevant to routine diagnostic medical procedures. Sykes and Hooker are presently studying the effect of lower dose rates on mutations in the mice using cobalt-60 irradiation facilities at ANSTO in collaboration with radiation dosimetry experts Dr Henk van der Gaast, Justin Davies, Allan Murray and radiation biologists Dr Renate Domel and Dr Bill Burch.

Approaches are also being explored to understand the mechanism of inversion responses to low dose-rate, low dose radiation.

Fig. 2



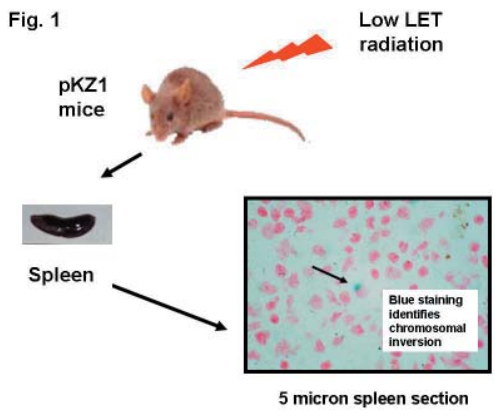
Low dose radiation dose-response curve. Inversions were induced in mice spleens at very low and at high doses of radiation exposure. Intermediate doses of radiation caused a decrease below endogenous inversion frequency. The straight line represents the LNT model.

How much radiation?

To put this story into context look at the following indicative common radiation doses

Conventional x-rays	
dental	5 - 10μGy
chest	20μGy
mammography	400μGy
CAT scan	
routine head	2600μGy
routine abdomen	13,000μGy

Fig. 1



Mice are exposed to low LET radiation. The spleen is then removed and frozen spleen sections are stained (blue) for a marker gene for DNA damage.

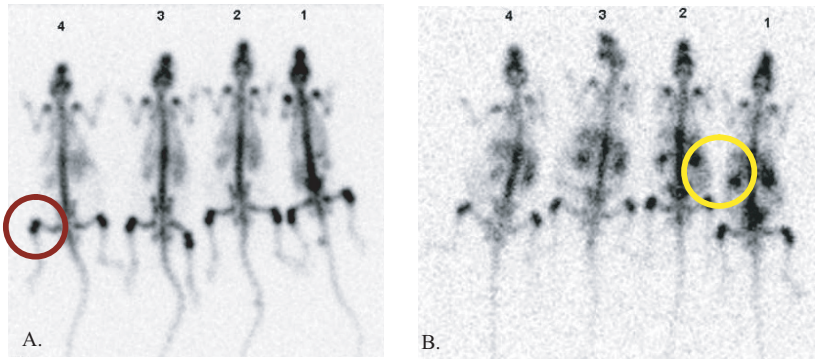
Complexes for the treatment of bone cancer

Complexes made from radiometals and phosphonates (from phosphonic acid) bind well with bone and also have potential as agents for the destruction of bone marrow, in patients with marrow-based malignancies, for example. ^{153}Sm-EDTMP (samarium-153 ethylene-diamine-tetramethylene-phosphonate) is such a complex and used to treat pain associated with metastatic bone cancer. Understanding the *in vivo* mechanisms of uptake of such complexes potentially leads to the development of more efficient agents to treat bone marrow and give more effective palliative care.

Dr John Webb and Danielle Meyrick at Murdoch University found that acidic conditions (pH 2 – 6) favour the uptake of samarium by both hydroxyapatite and bone powder. When administering ^{153}Sm-EDTMP to patients the pH can not be altered to improve the uptake, however, it is known that some cells at the bone surface can make local conditions acidic thereby favouring the ^{153}Sm-EDTMP uptake.

Also, part of the uptake can be accounted for by the ion exchange of calcium for samarium within the crystal lattice which occurs under normal physiological pH conditions. Spectroscopic evidence for the formation of a complex between hydroxyapatite calcium ions and EDTMP was provided by x-ray photoelectron spectroscopy.

Additionally, a study in rats of two structurally similar ^{153}Sm-phosphonate complexes — ^{153}Sm-AL245 and ^{153}Sm-CDTMP — provided strong support for the applicability of ^{153}Sm-CDTMP as an agent for treating bone marrow-based malignancies. Future studies will continue to assess its utility in this capacity.



Gamma camera images showing biodistribution in rats of ^{153}Sm-CDTMP (A) and ^{153}Sm-AL245 (B) 6 hours post injection. Note the high uptake in the joints (red circle) liver (yellow circle).

Trying to understand Alzheimer's disease

It is without dispute that Alzheimer's disease (AD) is an increasingly important health problem in Western Societies in this century.

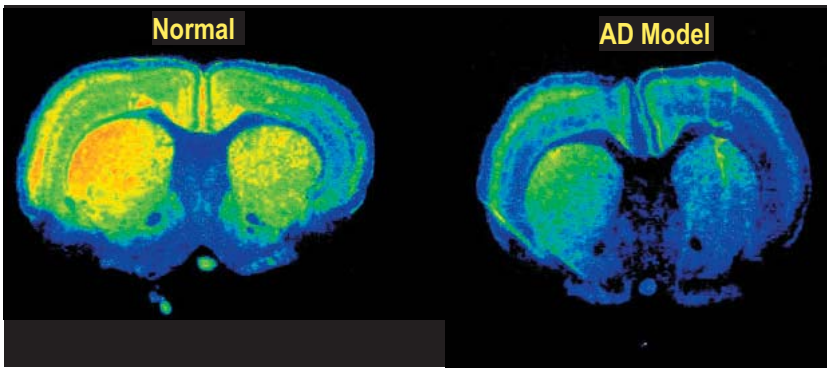
Some nerve cells rely principally on acetylcholine for the transmission of signals. These are known as the cholinergic system. Deficiencies in cholinergic markers, like acetylcholine and associated compounds, contribute significantly to the development of AD symptoms. For many years this has been the basis of the hypothesised link between such deficiencies, a relatively selective vulnerability of the cholinergic system and AD.

Reduction of receptors sites for acetylcholine, in particular nicotinic acetylcholine receptors (nAChRs), in the brain have been observed suggesting that investigation and imaging of cholinergic neurotransmission pathways would provide a better understanding of the disease process.

Associate Professor Michael Kassiou, Dr Jasmine Henderson and Mitchell Quinlivan from the Department of Pharmacology at the University of Sydney in collaboration with Dr Andrew Katsifis, Filomena Mattner and Patrice Ballantyne from ANSTO Radiopharmaceuticals have developed an animal model of AD allowing them to study changes in nAChRs.

In this model cholinergic nerve cells were destroyed using a neurotoxin injected into the rat brain and the resulting deficit was validated using behaviour and immunohistochemistry. A specific radioligand that binds to the nAChRs was used to evaluate differences in normal and diseased animals clearly demonstrating that the ability to measure changes in nAChRs in AD which was consistent with the number of active neurons.

These findings further strengthen the link which has been hypothesised between degeneration of the cholinergic system and AD, leading to the possibility of earlier diagnosis of the onset of AD



Comparison of in vitro autoradiographic images of nAChRs clearly shows a higher density in normal compared to lesioned AD rats.

Research Highlights

Environmental Science

A new approach to managing saline groundwater

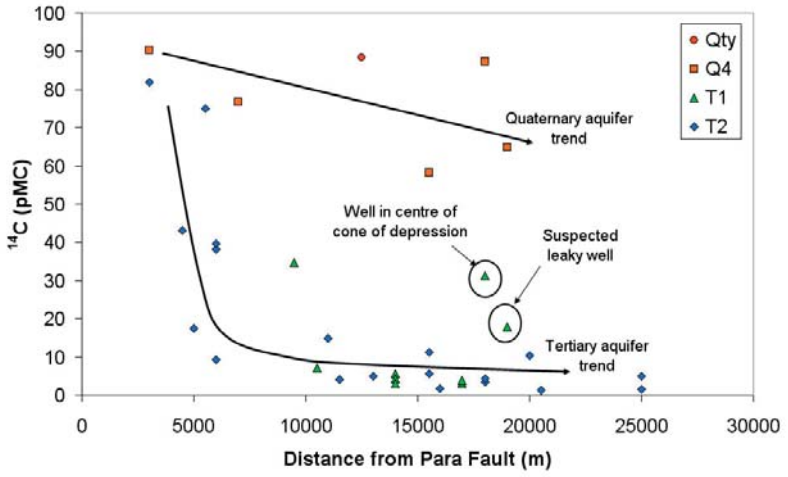
Dryland salinity is one of Australia's most pressing environmental problems. Areas affected by dryland salinity are common at the margins of the southeast Murray Basin, generally occurring where the basement hills flanking the basin meet the plains.

It works like this, land clearing increases the recharge shallow aquifers, causing water tables to rise and increasing evapotranspiration (evaporation from soil and transpiration from plants). This increases the salinity of groundwater and soils.

What is less well understood is whether increased recharge of shallow aquifers occurs mainly on the hills or across the landscape in general.

Dr Ian Cartwright from Monash University in collaboration with David Stone from ANSTO has carried out hydrogen-3 and carbon-14 dating of groundwater together with studies of groundwater chemistry, stable isotopes, and physical hydrogeology. This combination of measurements shows that increased recharge in dryland salinity-affected regions near Benalla, Victoria, occurs across the entire area, not just on the hills. The data also indicate that zones of groundwater discharge at breaks of slope periodically become recharge areas following winters with high rainfall, and this recycles saline groundwater into the aquifers.

These results have significant implications for management of dryland salinity. In particular, management of the areas that alternate between discharge and recharge is crucial as these are where the highest salinity groundwater most commonly resides. Currently, this water is recycled into regional flow systems during recharge events causing potential problems further down the catchment. Lowering the water table in these areas may prevent this recycling as well as potentially reducing salinity by reducing rates of evapotranspiration. Failure to reduce recharge on the hill slopes and at the break of slope will result in the continued generation of saline groundwater and the potential spread of salinity-affected areas as the water table continues to rise.



Graph of carbon-14 versus the distance from the Para fault of Quaternary and Tertiary aquifers in the North Adelaide plain

Salinity leakage and aquifers

In the North Adelaide Plain, sources of fresh ground water in Tertiary aquifers are threatened by significant increases in salinity. Excessive pumping of water from these aquifers is likely to induce lateral and vertical movement of saline groundwater either from more saline areas in the aquifer itself, or from other aquifers through semi-impermeable formations or through leaky boreholes that interconnect aquifers. In addition, development of artificial recharge of the confined aquifers — when treated waste water is injected into aquifers for storage — emphasises the importance of understanding groundwater flow rates and inter-aquifer relationships.

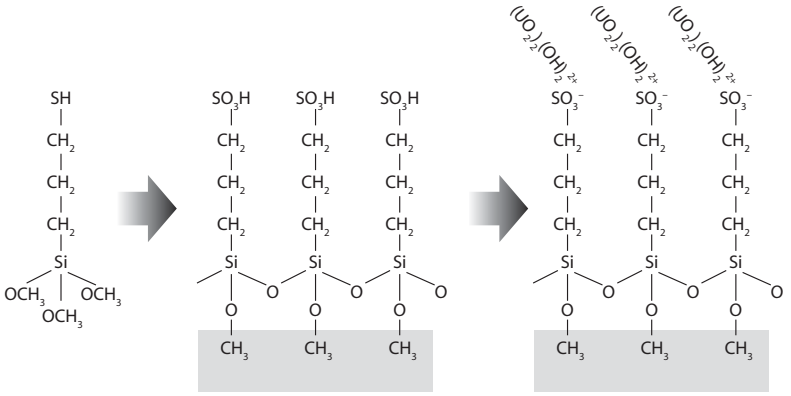
Dr Corinne Le Gal La Salle of Flinders University conducted a project in collaboration with the Department for Water Land and Biodiversity Conservation, ANSTO and CSIRO Land and Water to estimate groundwater residence time and stress in a multilayered confined aquifer system.

Corrected carbon-14 ages indicate that groundwater residence times range from the present to 25,000 years. The contrast in signature between the Tertiary aquifer groundwaters showing mainly low carbon-14 activities, and the Quaternary aquifers, displaying relatively elevated carbon-14 activities, indicates carbon isotopes can be used as an indicator of leakage from the Quaternary into the Tertiary aquifer in combination with other hydrochemical tracers.

This was confirmed with one well which was suspected to be leaking showing a relatively elevated carbon-14 signature (see figure to left). In addition, wells near the centre of the cone of depression display anomalously high carbon-14 activities, which may also be an indication of modern recharge encouraged by downward leakage through aquitards or through leaky wells.

Novel materials for the decontamination of water

The possible use of conventional weaponry containing radioactive elements by terrorist organisations is currently being discussed by defence agencies. The detonation of even a small conventional device containing uranium, plutonium or fission products into a city water supply would be enough to affect the lives of city populations. Hence, the ability to purify water contaminated with such elements is of great interest for any society and increases its capability to minimise the damage caused by accidental or deliberate contamination of potable water. Currently, no mature technologies are available to do this, especially in case of plutonium.



Mercaptopropyltrimethoxysilane (left) is deposited onto a metal oxide substrate and oxidised in order to form a sulphonate terminated self-assembled monolayer (middle). Immersed into water, the sulphonate group deprotonates and forms a negatively charged surface. Metal cations and their hydrolysed species are electrostatically attracted and immobilised by the surface and can removed from water (right).

Professor Peter Majewski from the University of South Australia and Dr Victor Luca at ANSTO are using composite materials containing silane-based self-assembled monolayers (SAMs). A SAM is a very thin (one nanometre) charged layer of molecules standing next to each other on a solid surface, see diagram to left.

They are investigating both the synthesis and chemistry of such materials and the effect of parameters such as temperature, time, type of SAM, and pH on the deposition of particles of these elements from water. The studies have a strong interdisciplinary character, including materials science, nanotechnology, organic and environmental chemistry and water treatment. As well as fundamental investigations the project will include applied studies on the processing of novel devices for water purification. This interdisciplinary approach is believed to provide maximum efficiency with respect to scientific and technical outcomes.

Dating groundwaters in western Victoria

Dryland salinisation is a major problem in western Victoria, affecting large areas of otherwise prime agricultural land and increasing the salinity of lakes in the area. To manage the problem and develop appropriate remediation strategies, it is necessary to determine the major recharge areas where groundwater enters the system, how quickly groundwater is moving through the aquifers, and how rapidly any changes, for example revegetation, will result in improvements.

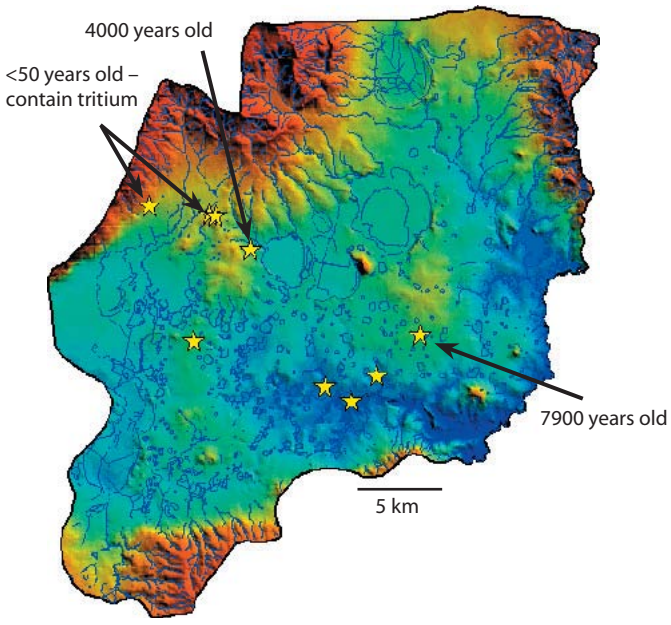
Tritium and carbon-14 dating of groundwaters in this area by Dr John Webb, Darren Bennetts and Matthias Raiber at La Trobe University are helping to prioritise management strategies. They have shown that the major recharge areas on the basalt plains are the volcanoes and the youngest basalts, less than 300,000 years old. Tritium dating reveals that the groundwaters beneath these areas are often less than 50 years old as rainwater can infiltrate rapidly through the thin, stony soil.

On the 2 - 4 million years old basalt plains rainwater infiltrates very slowly through the thick clay soils. It is then concentrated by plant transpiration and evaporation within the soil, becoming very saline by the time it reaches the groundwater. Carbon-14 analyses date these groundwaters as up to 20,000 years old and show that they take thousands of years to travel tens of kilometres.

Clearing native vegetation for agriculture increases the amount of rainwater infiltrating to become groundwater causing watertables to rise. This brings groundwater to the surface where evaporation concentrates salts in the soil.

The most common remediation strategy for dryland salinity is revegetation in areas of maximum recharge. While the studies show that revegetation should be concentrated on the volcanoes and younger basalts, this would mean taking a large area of quality agricultural land. Additionally, any noticeable effect will take decades to appear because of the slow groundwater movement in the basalt.

Tritium dating of groundwaters in discharge areas, that is where the groundwater comes to the surface, revealed that they often contain a component of relatively modern water, less than 50 years old, even when they lie at the end of a long groundwater flow path. This finding indicates that intercepting local infiltration by tree planting adjacent to the discharge site will help to reduce the watertable level, giving more rapid results for a smaller effort.



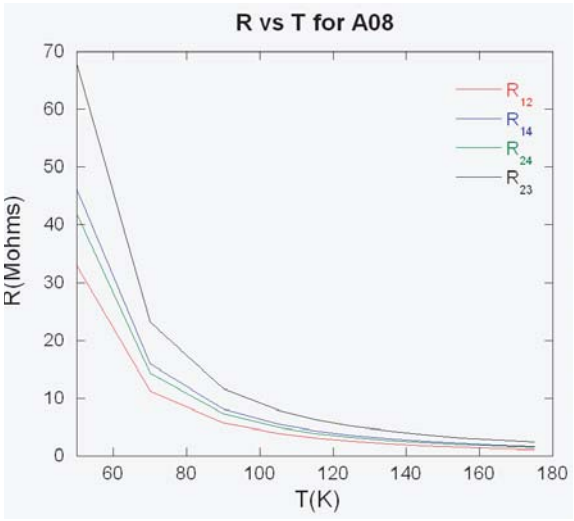
Research Highlights

Materials – Properties and Engineering

Ion implanted polymers for soft electronics

Many researchers believe that the next generation of electronic materials will be based upon conducting polymers and other conducting organic systems. These so-called “soft electronic” materials are perceived to have a number of distinct advantages over their “harder” inorganic cousins, namely: lower cost, significantly easier processing, better environmental profile, and improved mechanical robustness. The first soft electronic products are already in the market, mainly in display applications; and true soft circuitry and memory are not far behind.

Conjugated polymers, like polythiophenes and polyphenylenevinylenes, are the most popular soft electronic materials. They can be cast from solution, screen printed as liquids, spun or dip coated onto surfaces. They can also be patterned using standard lithography. However, polymer morphology, stability and charge carrier mobility remain as significant challenges for conjugated polymers.

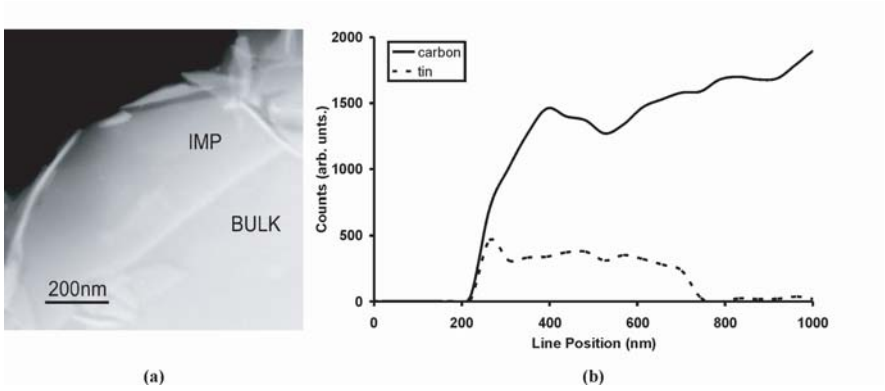


Resistance vs temperature for a tin ion implanted polyetheretherketone sample. The material shows room temperature resistance of ~1MW, with a corresponding conductivity of ~10^{-2}Scm . The behaviour (increasing resistance with decreasing temperature) is characteristic of a semiconductor or insulator – not a metal. The 4 curves represent measurements in the 4 Van der Pauw configurations.

Dr Paul Meredith and Eric Tavenner of the University of Queensland are taking an alternative approach to producing cheap, flexible soft electronic materials. They are using ion implantation methods to create electrical conductivity in the near surface of conventional, insulating polymers such as polycarbonate or polyetheretherketone. The accelerators at ANSTO are able to produce a stream of energetic metal ions which are fired at piece of polymer. The ions become imbedded in the surface layer and producing semiconductor characteristics. Recently they have shown that even higher levels of conductivity can be achieved in this way, and near metallic levels of conductivity have been achieved.

The tin metal vapour ion source at ANSTO has been used to produce tin ion implanted polymers with room temperature conductivities of about 10^{-2}Scm^{-1}. Before implanting, the native polymer conductivity was 10^{-16} Scm^{-1}! The structural and electrical characteristics of these materials show promise for applications as semiconductors or Coulomb gap systems. Additionally, it appears as though the ion beam is responsible for “graphitising” the implanted region – bonds within the surface are broken and reform to yield a carbon rich region. Hence, the increase in conductivity is due to the formation of a tin doped carbon rich surface layer.

‘We are still studying the synthesis, structure and properties of these materials’ says Meredith, ‘to gain a fuller understanding these systems. I believed that they have significant potential as cheap, robust soft electronic materials, especially when one considers that ion beams are capable of nano and micro-patterning.’



Scanning transmission electron microscopy image of tin ion implanted polyetheretherketone sample (cross-section of the implanted surface). Implanted region is specified by IMP and native PEEK region is specified by BULK.

Heavy metal removal from drinking water

The most toxic metal ions in our environment, and those considered most harmful to humans, are cadmium, lead and mercury. All three cause significant disruption in processes involving enzymes due to their affinity for sulfur containing amino acids such as cysteine residues.

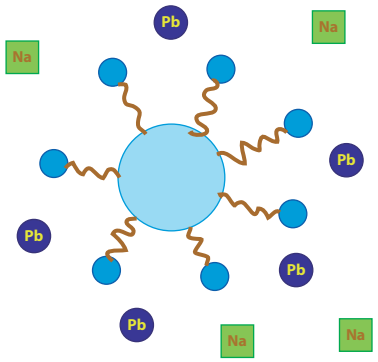
These cysteine residues are present in proteins and enzymes in our bodies and their interaction with heavy metal ions has serious and detrimental health effects. The extraction of these heavy metals from drinking water is therefore of considerable importance.

Ever since their introduction the Australian Drinking Water Guidelines have become more stringent. Currently they put very low limits on the concentration of these metal ions of less than one part per million (ppm); 0.002ppm (cadmium), 0.01ppm (lead) and 0.001ppm (mercury). The methods presently employed to achieve these limits are ion-exchange and reverse osmosis. If the guidelines are altered to encompass even lower accepted limits, will these methods be able to achieve the new limits?

A team comprising Craig Bell, Michael Monteiro, and Lawrence Gahan at the University of Queensland, and Suzanne Smith at ANSTO, is aiming to develop materials suitable for the removal of the heavy metal ions at levels approaching parts per trillion (ppt). This is to be achieved by the preparation of polymer nanoparticles containing sites with geometries specifically designed for the selective removal of these heavy metal ions.

In order to test the efficiency of these polymer nanoparticles, radioisotopes of the heavy metal ions were used which allowed the team to determine metal ion uptake capacities and the selectivities of these materials for the metal ions being studied. The presence of radioisotopes can be measured with a gamma counter and the most efficient formulation of polymer can then be determined and further exploited.

The team has found some nanoparticle systems which are effective and they are now tweaking the design of these particles to optimise selectivity for specific metal ions as well as their efficiency at binding them up to achieve ppt concentration in water.



Polymer nanoparticles

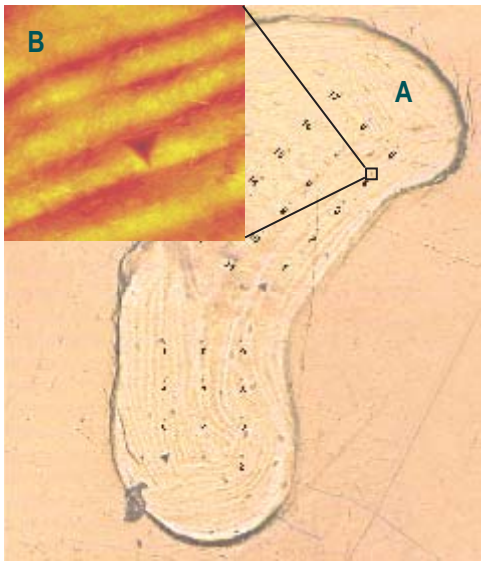
Understanding osteoarthritis

Osteoarthritis is an extremely painful and immobilising disease, which affects approximately two million Australians. Such musculoskeletal disease in this rapidly aging population is becoming a significant health cost in the Australian community given that the number of people over 65 is expected to double by 2025.

Treatment and prevention requires an understanding of bone on many levels. One of these relates to the mechanical stability of the diseased bone. Bone is basically a sponge-like matrix and the individual bone struts through the centre of the bone are called trabeculae.

The material properties of osteoarthritic and control trabeculae were examined by Associate Professor Joseph Shapter and Jon Norman from Flinders University, Allan Pring and Mike Snow from the South Australian Museum, Nick Fazzalari from the Institute of Medical and Veterinary Science, and Bill Skinner from the University of South Australia. ANSTO's nanoindenter and atomic force microscope were used to study the mineralisation of bone samples and then relate this to material properties such as brittleness which is an important issue for disease sufferers. More brittle bone breaks more easily.

Significant differences were found between the mechanical properties of individual trabecular struts of the osteoarthritic and normal samples. Finding such high levels of difference in properties at this small scale is an important early advance in understanding osteoarthritis and in developing more effective treatments.



Left
A) Optical Image showing a series of indents in a bone sample immobilised in PMMA
B) Zoom of one of the indents taken using AFM

Research Highlights

Materials – Structures and Dynamics

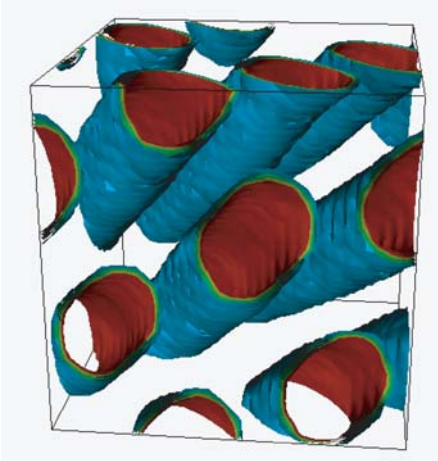
Transition metal oxide-based films

Mesostructures are aggregates of molecules with a well-defined structure on a scale of 20Å (20 x 10^{-10} m) or more. Liquid crystal is an example of a mesostructure. Some can be used as a template for other materials, for example inorganic oxides, to produce mesostructured material as a powder or as a thin film. After removal of the template, the inorganic oxide can contain pores with diameters in the size range of 20-500 Å and is said to be mesoporous.

The high surface area of some mesoporous materials have made them the focus of great interest as they have potential application in the fields of optics, electronics, chemical sensing, and catalysis.

Dr Mark Henderson, Adrian Hawley and Professor John White at the Australian National University are particularly interested in thin films based on oxide networks, particularly titanium oxide and zirconium oxide, that could find use in catalytic reactions where high surface area is of the utmost importance. Recently they monitored the growth of titanium oxide and zirconium oxide multi-layered lamellar films at the solid/liquid interface using the angular dispersive Bragg Institute's X172 reflectometer.

Their work offered three novel features of value in studying transition metal oxide-based films. First, they demonstrated that lamellar mesostructured titanium oxide and zirconium oxide -based films could self-assemble at the solid/liquid interface. Secondly, they showed how the lamellar order within the thin film could be increased by varying the solution pH. Thirdly, they showed how the reflectivity from the titanium oxide-based film could be highlighted.



Mesoporous structure

Development of hydroxyapatite ceramics

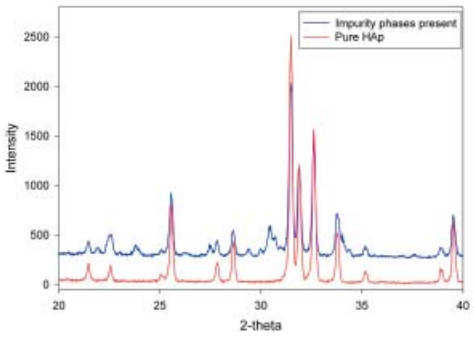
Understanding how inorganic materials form in biological systems is of great importance in biomedical science and is inspiring innovative approaches in synthetic materials chemistry.

Professor Arie van Riessen, Catherine Kealley, and Dr Robert Hart of Curtin University of Technology, and Dr Margaret Elcombe at the Bragg Institute, ANSTO, are aiming to create a material that is biocompatible with bone, for use in a ceramic implant that will have high mechanical strength and resilience, and withstand exposure to chemicals.

Their method included precipitating hydroxyapatite, $Ca_{10}(PO_4)_6(OH)_2$, from calcium nitrate and dibasic ammonium phosphate under tightly controlled conditions including: pH; temperature; rate of reactant addition and maturation time. It is vital that the hydroxyapatite produced is free of impurities as these have a detrimental effect on the strength and resilience.

Through the use of x-ray diffraction for confirmation of the crystal structure, the team has been able to identify the critical factors, pH, temperature, rate of reactant addition and maturation time, which control the rate of reaction. If one of these factors is not controlled during the precipitation impurities such a tricalcium phosphate, $Ca_3(PO_4)_2$, form.

Conditions for producing a pure biocompatible material have been determined as this is imperative for strength in applications such as a replacement hip joint. As yet, this material is not as strong or as resilient as human bone. Further work will look into the development of a hydroxyapatite and carbon nanotube composite material, with the aim of achieving a strength similar to that of human bone.



Comparison of x-ray diffraction data from pure HAp and HAp with impurity phases (offset vertically)

Viability of new repair technique for airframes

Damage in airframes is repaired either by grinding out shallow defects or by patch repair for larger defects. However, both of these techniques are time consuming and do not easily deal with damage that extends into the airframe's structure. On the other hand, friction stir welding is a promising alternative technique for the repair of damage in airframes as it is fast, can be applied to cracks or larger defects and does not add to the weight of the structure.

All welds have residual stresses associated with them as a result of the welding process. Quantifying the magnitude of residual stress around welds is a key step in determining the integrity of the weld repairs in service.

Professor Valerie Linton and Simon Renc from the University of Adelaide have been using the neutron diffraction strain scanner at ANSTO to quantify the residual stresses around friction stir repair welds in the 7XXX series aluminium alloys used for manufacturing airframes. The magnitude of these residual stresses has been determined in both freshly made and aged welds in a project aimed at proving the viability of this new repair technique.

The results of this work to date have shown that it is possible to quantify the stresses around these welds, thus offering the possibility of predicting how the welds will perform in service. Overall the work is contributing to the demonstration that friction stir welding is a viable technique for repairing airframes with the attendant significant reduction in turn around time required for the repair of these structures.

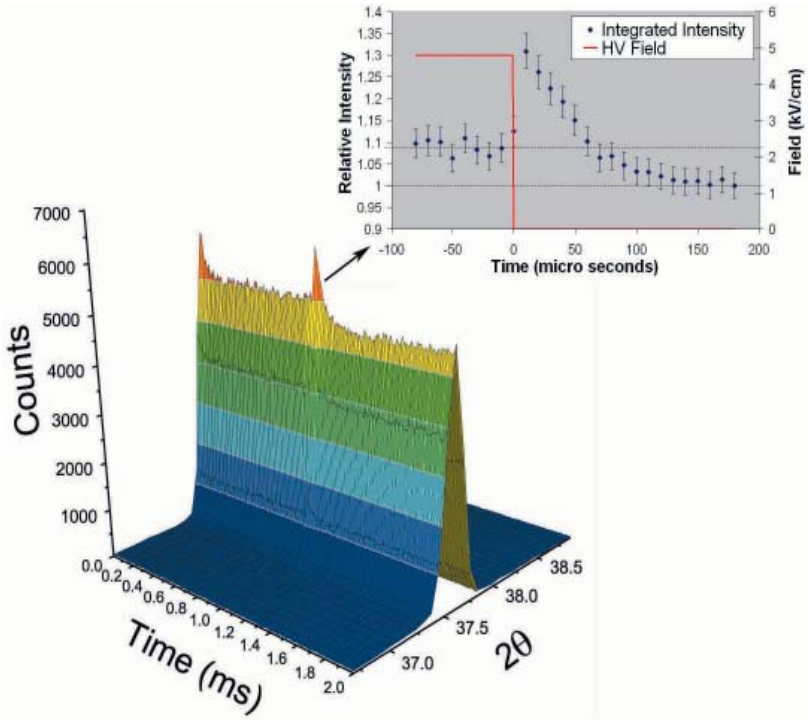
Cross section through a friction stir weld in a 8mm thick 7075 aluminium alloy, the scale is in millimetres

A new capability for observing neutron diffraction intensities

As part of the continuing development of neutron scattering instruments at ANSTO the strain scanner has been adapted so that diffraction intensities can be observed in real time during the application of electric-field pulses. A team comprising Associate Professor Trevor Finlayson and John Daniels, from Monash University, Dr Andrew Studer from ANSTO and Dr Mark Hagen from ORNL have developed this capability using a stroboscopic technique.

They have applied continuous high-voltage pulses to samples in the beam. The apparatus is capable of switching voltages of up to 10kV at frequencies up to 10kHz. The timing resolution of approximately 25 microseconds (μs) allows for the observation of structural relaxations occurring over times greater than 25μs.

Their initial experiments have involved the switching of single crystals of triglycine sulfate from the paraelectric disordered state to a ferroelectric ordered state. The most interesting results are observed in the behaviour of the (060) Bragg peak as a function of time, during the application of a 500Hz square wave with a field strength of 4.8kV/cm, see diagram right.



Above: (060) Bragg peak intensity of TGS during the application of a 500Hz square wave, field on from 0-1ms, field off 1-2ms. Data were separated into 200 time frames within the 2ms cycle.

Left: Relaxation of (060) Bragg peak intensity after the removal of a 4.8kV/cm field. The upper and lower dashed lines represent the field on and field off intensities during the application of the 500Hz square wave respectively.

The AINSE Winter School

Nuclear techniques applied to natural processes

The Winter School targets senior undergraduates from member universities and applications for the Winter School close in mid April. For more information see our web site or consult an AINSE Councillor.

The seventh AINSE Winter School on nuclear techniques applied to natural processes was held at the Lucas Heights Science and Technology Centre from Saturday 3 July to Wednesday 7 July 2004 with a great deal of input from over twenty ANSTO staff, university staff and half a dozen research students.

Thirty-seven senior undergraduate students participated in the Winter School; 17 females and 20 males. Their principal discipline interests were as follows

Discipline	Number
Archaeology	1
Biosciences	3
Chemistry	8
Environment	5
Earth sciences	3
Engineering	5
Nuclear medicine	1
Physics	10

Left to right: Anthony Mays from Monash University, Hannah Jane Joyce from the University of Western Australia, Andrew Vella from University of Technology Sydney, and Tony Aitchison from Flinders University conducting the radiation science experiment

A background lecture and an experimental session was provided for in each of the following areas:

- neutron diffraction techniques and applications
- use of natural radioactivity in environmental studies
- radiation science
- applications of gamma ray probes
- ion implantation, RBS and SIMS

On the Saturday evening Dr Cait Maloney General Manger, ANSTO Safety and Radiation Science, spoke on her research and experiences in the field of safety and radiation science.

Dr Ken Doolan, helping Sarah Midgley from the University of Western Sydney and Floss Pitson from the University of Ballarat with the radiation science experiment

Left to right: Supakit Charnvanichborikan from ANU and Justine Lewis from the University of Canberra at the van der Graaff accelerator during the ion implantation experiment

Left to right: AINSE Postgraduate Scholars Andrew Wroe, Andrew Whitten, Catherine Kealley; Dr Ian Smith CEO ANSTO, Angus Macgregor and Tim Ralph. The two Andrews and Tim were once Winter School students.

On the Monday evening Dr Julia James gave a presentation entitled *A Multidisciplinary Science – Speleology.* Dr James is a visiting research fellow at the University of Sydney and now devotes herself full time to speleological research.

On Tuesday evening students took part in a discussion lead by Dr Miriam Goodwin, from ANSTO Government and Public Affairs on *Give and Take – the relationships between ANSTO and the Government, national and international communities*

The following AINSE postgraduate scholars gave short presentations on their research:

Catherine Kealley – *Development and application of hydroxyapatite/nanotube bio-ceramic composites for medical prostheses*

Angus Macgregor – *Establishing lead-210 and AMS radiocarbon chronologies for palaeo-limnological reconstructions of the Snowy River floodplain*

Tim Ralph – *Patterns of fluvial sedimentation in a wetland using natural and anthropogenic radionuclides*

Andrew Whitten – *Electrostatic properties of molecules from x-ray diffraction data*

Andrew Wroe – *An AINSE Winter School Student's Ph D – microdosimetry*.

Acknowledgements

AINSE is indebted to Dr Ian Smith, ANSTO's Executive Director, for supporting the Winter School, to the many ANSTO staff members who contributed their time and talent, to Gerald Laurence, Julia James, and Ken Doolan from the universities involved in the planning and implementation of this year's Winter School. AINSE particularly thanks the postgraduate scholars who were demonstrators for the experiments, as well as being guides and mentors for the students and who provided a tangible link between the undergraduate world and that of a research scientist.

Anthony Mays from Monash University at one of the neutron scattering instruments on HIFAR

Left to right: Rodi Sferopoulos from Victoria University, Betine Nuhiji from Deakin University and Matthew McMinn from the University of Tasmania getting acquainted on the harbour cruise

2004 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 one conference in 2004. It sponsored two neutron scattering workshops, and provided travel bursaries for research students to attend the Australian Synchrotron Summer School. In addition, two students received travel scholarships to attend international meetings.

4th AINSE Symposium on Neutron Scattering

The 4th AINSE Symposium on Neutron Scattering was held at Lucas Heights in Sydney on the 13-15 December 2004 at AINSE Lucas Heights. There were 73 participants including five from four countries. Ten Australian and New Zealand universities and three research centres were represented. Of the attendees there was one undergraduate, 14 postgraduates and 15 postdoctoral fellows.

Plenary lectures were given by AINSE President John White, Australian National University, on *Mimicking Biomineralisation*, Dimitri Argyriou from Hahn-Meitner-Institut, on *Structure and Superconductivity in Layered Cobaltites*, and Mark Hagen from SNS on *Spin Waves and Phonons in the LCMO CMR*. Both international speakers were sponsored by the Bragg Institute. The plenary lecturers and contributing speakers covered an extensive range of topics including: residual stress analysis, synthetic lung surfactants, layered molecular and rare earth magnets, and *in-situ* catalysis structure among others. These investigations benefited from applications of the wide range of techniques available from neutron scattering, including conventional neutron diffraction, small angle neutron scattering, reflectometry, and polarized and inelastic neutron scattering.

The symposium was preceded by a workshop designed to introduce neutron scattering techniques to new users and it was aimed at post graduates and post doctoral fellows.

Attendees at the 4th Neutron Scattering Symposium

Workshop on Data Visualisation, Reduction and Analysis at Australia's Replacement Research Reactor

The Workshop on Data Visualisation, Reduction and Analysis at Australia's Replacement Research Reactor was held at ANSTO Lucas Heights on 30th and 31st March 2004. International invited speakers included Dimitri Argyriou from Hahn-Meitner-Institut, Benno P Schoenborn and Jill Trewhella from Los Alamos National Laboratory.

There were 53 attendees, including 17 people from 10 AINSE member universities.

Photons@Work, Australian Synchrotron Summer School

Photons@Work, Australian Synchrotron Summer School at ANU from 27 January to 5 February 2004. The School featured internationally respected experts drawn from both overseas and Australia. The program combined formal teaching and lecture sessions with informal discussions and tutorials. The primary target audience was young scientists, including honours students, graduate students and early-career researchers, from Australia and overseas in the biological, medical, chemical, earth, materials and physical sciences and engineering. The Summer School aimed at enabling people not yet using synchrotron radiation to identify new experimental techniques relevant to their area of study and current synchrotron users to enhance their skills.

Travel bursaries were provided to assist travel expenses for 14 students from 10 universities who attended this meeting.

Workshop on Polarisation Analysis and Inelastic Cold-Neutron Scattering at Australia's Replacement Research Reactor

The Workshop on Polarisation Analysis and Inelastic Cold-Neutron Scattering at Australia's Replacement Research Reactor was held at ANSTO Lucas Heights on 27 and 28 January 2004.

This was the tenth Instrument Workshop supported by AINSE and run by the Bragg Institute. There were 30 participants who came from six Australian Universities, three ANSTO Divisions, and five overseas countries in Asia, Europe and North America. All participants had the opportunity to give their vision for work in 2005 and beyond. In addition four invited talks were presented as follows:

Scientific opportunities with polarised and cold neutron inelastic scattering
Steve Nagler, Oak Ridge National Laboratory, USA; Feri Mezei, Hahn Meitner Institute, Germany; Kazu Kakurai, Japan Atomic Energy Research Institute, and Trevor Hicks Monash University;

Using neutrons to answer fundamental questions about frustrated quantum antiferromagnets Ross McKenzie University of Queensland;

Using neutrons to answer fundamental questions and address technologically important issues: case studies in magnetism Robert Stamps University of Western Australia; and

Possible scientific program and plans for a cold-neutron 3-axis spectrometer from Taiwan Wen-Hsien Li, National Central University, Taiwan.

International Conference Travel Scholarships

The surplus from the International Congress of Radiation Research has been set aside for travel and accommodation subsidies for students and post doctoral fellows who are presenting their work at international conferences. In 2004 two students from the University of Wollongong were supported from this fund to attend IEEE Nuclear Science Symposium on Medical Imaging Conference and Semiconductor Workshop. One of the students, Andrew Wroe was awarded the prize for best student poster. The other student Dale Prokopovic was given a slot for an oral presentation.

People wishing to access this fund should prepare a brief submission giving the name and date of the conference, a copy of their abstract, the AINSE Award number(s) and Awardee's name for the research on which the abstract is based, and an indication of whether it is to be an oral or poster presentation. A travel budget including any addition travel support which has been accessed should be included. The scholarships take into consideration whether the conference will produce a published proceedings, and whether the papers are refereed.

Andrew Wroe was in Rome for the IEEE meeting He was awarded the prize for the best student poster. This is not it.