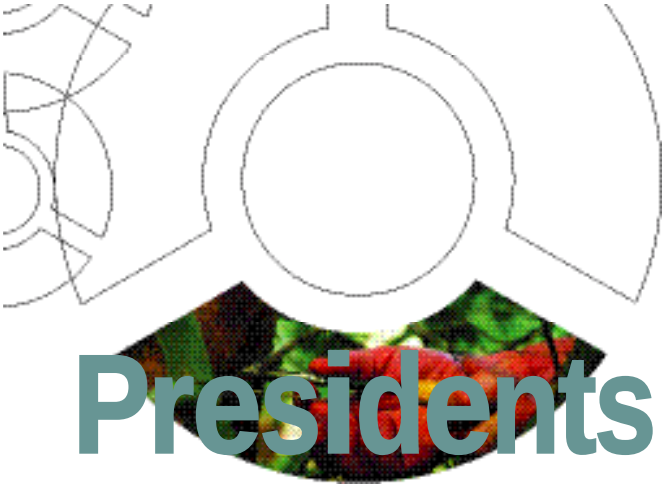


Presidents Report

AINSE's unique national collaboration is now firmly into its 5th decade; a singularly remarkable testimony to growth and initiative in the wider application of nuclear science based methodology. AINSE now has every federally funded university within its membership - together with ANSTO, the University of Auckland and the New Zealand Institute for Geological and Nuclear Sciences. Having attained the peak of membership involvement this must not be a prelude to relaxation and stagnation. AINSE has continued to evolve not just in numerical membership but more importantly in the range of disciplines; its quality research facilities; increasing student involvement and published output.

The evolution of AINSE is proceeding along several lines. In the last year it has been recognised that certain closely defined specialist areas of AINSE support are no longer growing. Ten years ago the fields of Radiation Science and Plasma Physics played a substantial role in AINSE activities. Environmental Science and Archaeology were not overtly designated areas of AINSE support; now the situation has changed. Radiation Science for example has gained several Gold Medals for research excellence. Two major centres of excellence surrounded these awardees. The areas are now better described as material science programs. The fundamental radiation science is now a stable platform from which applied fields can securely build. Radiation oncology; nanoparticles, novel materials, polymer production and development, environmental remediation etc are fields where this is occurring. It is now a valuable contribution to material sciences, biomedicine, environmental analysis and control and NOT a purely isolated piece of “radiation science”. These advances are better assessed in the arena of their application area rather than at the “pure science” level.

AINSE's project assessment procedures this year have followed through with this idea. New panels are now focussed on the areas where there is a demonstrable increasing demand for support from productive researchers. The five areas identified were: Environmental Sciences; Materials Properties and Engineering; Materials Structures and Dynamics; Archaeology and Geosciences; and Biomedical Science and Biotechnology. One feature of these panels is that the prime focus of the assessment is on the quality of the science with technical feasibility a requirement but not the fundamental one. Further the specialist panels will give critical supportive feedback to all applications not just the unsuccessful ones. Panel membership will periodically be changed.

It is immensely pleasing to see the number of project proposals coming from Arts faculties across the country. This is quiet testimony to the activities of AINSE being promoted by AINSE Officers/Councillors and ANSTO personnel during national meetings, conferences, workshops and personal visits.

Student involvement in AINSE has been increasingly significant. The Winter School for senior undergraduates continues to be highly successful and produces numbers of follow-on projects. Subsequent honours projects and PhD programs applying for AINSE Postgraduate Research Awards are increasing. The Postgraduate Award Committee in 2002 had the task of assessing over 40 very high standard applications for AINSE Postgraduate Research Awards. The later deadline for applications enabled students to fully explore facility and supervision arrangements with ANSTO officers.

The immediate future for AINSE is a challenging one. The new Tandem accelerator won by AINSE from a LIEF grant application is about to be commissioned and will require development of the facility as a whole to generate forecast productivity. The automatic sample preparation system and mass analyser purchased by AINSE will be a significant auxiliary system which will, when commissioned, lead to a substantial increase in sample throughput and data accuracy.

The replacement research reactor will give AINSE an opportunity to participate in the development of this new national facility. The availability of a world class neutron source will boost AINSE's members projects already acknowledged as excellent. The success of our members in competition for time on the ISIS facility at the Rutherford Laboratory in the United Kingdom is testimony to the highest regard with which this science is held.

One area of difficulty is the restriction on AINSE activities placed by the limited financial resources derived from the subscription arrangement. The subscription base grows slowly as university uptake is assessed and averaged over a five-year period. Costs increase annually! The recent review of ANSTO facility costs resulted in very significant increases in some areas. I believe that AINSE must look outside its subscription base to fund facility access. The specialist committees are centres through which researchers can focus their efforts and make group applications to ARC and outside bodies. The demonstrated team strength of AINSE/ANSTO in winning ARC RIEF grants in the past is surely an indicator of the probable success of such ventures. Whatever the mechanism, the resource pool for facility access costs needs to be deepened.

On the wider stage, AINSE is assisting Australian institutions in organising International Congresses. The International Association of Radiation Research is holding its World Congress in Brisbane in August 2003 with AINSE as a major host. The South Pacific Environmental Radioactivity Association is assisted by AINSE as well as supporting a world congress of Radiopharmaceuticals in Sydney during 2003. AINSE's national linkages make us a key factor in unifying national collaboration.

I must end my term as AINSE President by thanking the members of the executive of AINSE for a stimulating series of meetings resulting in advantage to the AINSE collaboration. I wish the incoming president, Hans Coster, an enjoyable and productive time during his term of office. I can assure him that life will not be dull!

AINSE
Scientific Secretary's Report

Dr Dennis Mather
Scientific Secretary AINSE

Two thousand and two has been a year of some significant milestones for AINSE. The new ARC LIEF funded Tandetron which has been christened 'Star' was delivered on 23 October and its assembly commenced in November under the supervision of an engineer from HVEE. ANSTO Engineering did an excellent job of preparing the site for Star – including laying the floating cement slab on which it will sit within a flatness and level tolerance of 2mm. The issue of the ownership of Star has been resolved and it is to stay on AINSE's asset register, while the issue of insurance should be resolved early in 2003. We expect Star to be operational by the second half of 2003. The Experimental Analyser Isotope Ratio Mass Spectrometer was delivered in January 2003 and it should be fully functional well before Star. This equipment will ease the bottle-neck in AMS sample preparation facilitating a higher through-put of samples than is currently possible.

The second council meeting of the year was held in the Hunter Valley. They continue the process of reviewing AINSE's key performance indicators and working towards developing a strategic plan. The meeting proved to be somewhat longer than many people intended due to bush fires forcing road closures, while at the same time the rest of the AINSE staff had one eye on fires that were moving towards the office at Lucas Heights.

At the end of the year we started preparations for the ARC review of five years support for Australia's membership of ISIS, the world's most powerful pulsed neutron source. The review was held on 6 February 2003.

Neutron scattering workshops continued in 2002 with very well attended events at the University of NSW, for engineering applications, and at ANSTO, for earth scientists. These workshops have significantly increased the general awareness of the potential for using neutrons as a tool for better understanding the structure of matter. The workshops were conceived and designed to disseminate information on the potential capability of the Replacement Research Reactor, and to gather information on the types of analyses university and industry based researchers would like. I believe we will have an increasing number of new applicants over the next few years, many of whom will have attended these workshops.

The publication rate remained high with 277 references notified this year. Details can be found in section 2 of this report. First time award holders in 2002 represented 23 per cent of the cohort, which is slightly higher than last year's figure of 21 per cent. I attribute this, in part, to the diligence of our Councillors and to my university visit program; in 2003 I spoke with researchers and students at 23 universities. A higher proportion of award funds went towards facility costs, rather than travel and accommodation, than ever before. This reflects AINSE's efforts to encourage award holders to book the lowest possible airfares.

This year AINSE postgraduate award scholars included three previous Winter School attendees, reinforcing our belief in the effectiveness of the Winter School as a vehicle for spreading understanding of the opportunities that exist for research at ANSTO.

Many more Winter School students gain access to the facilities at ANSTO by means of an award

Council and Committees

While 2002 was the final year for Ron Cooper as President the Executive Committee voted for his continued involvement in 2003 on the Committee as immediate Past President, in recognition of the significant contribution he has made to the running of AINSE.

On the Council, changes include:

- The University of Auckland's Professor Tom Barnes, replaced by A/Professor Jim Metson
- Charles Sturt University's A/Professor Kevin Robards, replaced by Dr Michael Antolovich
- Griffith University's A/Professor Evan Gray, replaced by A/Professor Greg Hope
- University of Newcastle's Professor Ron MacDonald, replaced by A/Professor Bruce King
- University of New England's Professor Brian Stoddard, replaced by Dr Peter Grave
- Northern Territory University's, replaced by A/Professor David Parry
- Swinburne University of Technology' s Dr Eddie Bakshi, replaced by Dr Anthony Bartel
- University of Wollongong's, Professor Anatoly Rozenfeld, replaced by Professor Allan Chivas
- University of Canberra's A/Professor Andrew Cheetham, replaced by Professor Mohamed Khadra

The structural changes to the specialist committees has resulted in a uniform focus on the excellence of the science in

committees. We have reduced the number of committees to five, and have limited them to six members each, and we have made a commitment to refreshing membership of the committees on a regular basis. The specialist committee details can be found on page 4 to 7 of section 2. In 2003 new committees will be formed and selection will be based upon the quality of the nominations received.

AINSE is grateful for the dedication of all members of the various committees. Without their input the organisation would not be able to move forward.

Finances

The budget for 2002 awards was $1,584,767 and compares well with an uptake of $1,676,662, which includes $294,258 of carry over awards from previous years. This is the largest ever expenditure on awards and largely reflects a higher uptake of awards involving neutron scattering.

In 2002, income of $2,765,717 was made up of $1,351,577 from ANSTO's membership fee, $705,526 from university members, $494,090 from external grants, $209,664 from interest on investments, and $4,860 from other sources, see figure 1.

Membership subscriptions are reviewed annually to determine AINSE support for each university. On average, for the period 1997 to 2001 inclusive, universities received research and training benefits amounting to 3.61 times their subscriptions. For more information on performance indicators, see section 2, page 69.

The majority of AINSE funds are used to facilitate travel and access to Lucas Heights for university researchers and research students, see figure 2. University projects are supported mainly through awards to cover costs associated with operating ANSTO's facilities. AINSE's operating expenses in 2002 were $3,164,109, leaving a deficit for the year of $398,392. Funds have been set aside to finance the Accelerator, and automatic AMS sample preparation/analyser, both to be commissioned in 2003.

The Financial Statements for the calendar year 2002 presented in section 2 starting on page 10 were prepared by ANSTO and audited by Escott Aston.

Awards and postgraduate research awards

A total of 204 awards were made in 2002 and another 79 were carried over from previous years. Highlights are given on pages 6 to 15. Full progress reports for each of the projects can be found on our home page www.ainse.edu.au.

More funds were expended on AINSE awards in 2002 than ever before. Carry-over awards totalling $294,258 were largely made up of AMS projects, $123,255, and projects that were commenced in 2002 and not completed before the end of the year. A smaller proportion of award holders were unable to make arrangements to commence their projects in 2002 and made special arrangements to complete their projects before the end of February 2003.

In 2002, eleven of the thirty-four AINSE postgraduate research award holders received an award for the first time. During the year three PhD theses were received. The AINSE postgraduate research award holders accessed the facilities for a total of 348 days. In addition, another 94 students gained access to the facilities via awards held by their supervisors for a total of 776 days.

Details of the AINSE Winter School and Conferences can be found on pages 16 and 17 of this report.

Acknowledgements

I thank Irene Parker, Nerissa Phillips, Tanya Irvine, Andrew Henriksen and Sandy O'Connor for their calm support throughout the year. The President, Associate Professor Ron Cooper, has provided me with invaluable advice and tremendous support throughout the year. Professor Helen Garnett, the Chief Executive Officer ANSTO, has once again demonstrated her support and long-term commitment to AINSE.

My thanks go to all those from the universities and ANSTO, there would be hundreds, for their help, advice and good company throughout the year.

Finally, a special thanks to the manager ANSTO Communications Pam Keenan and graphic designer Steven Rosevear for their assistance in the making of this report.

Dr Dennis Mather

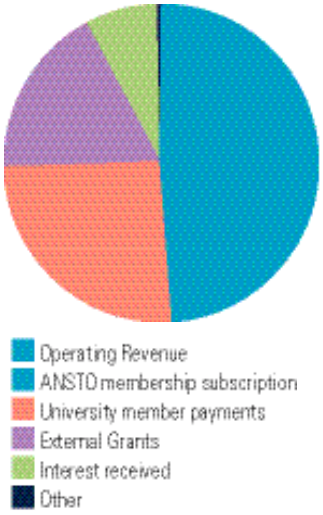
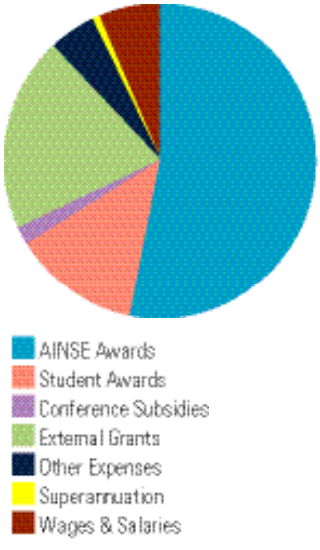


Figure 1. Operating Revenue



Research Highlights

Archaeology and Geosciences

Use of PIXE and SIMS in Economic Geology

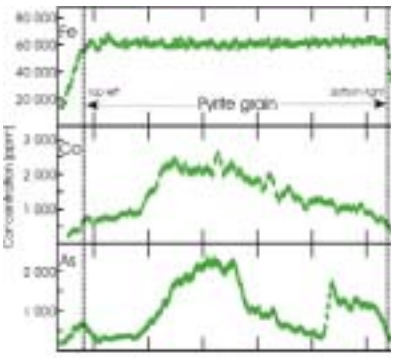
Study of the shape, chemistry and texture of minerals is particularly useful in deciphering the nature of fluid flow deep in the Earth's crust, and has direct application to understanding the genesis of hydrothermal ore deposits. The Ernest Henry copper/gold mine is one ore deposit formed via hydrothermal processes within the crust where mineralization was deposited in association with mixing of multiple fluids of distinctly different composition. However, one of the main questions still to be resolved is the origin of the dominant fluid components involved in mineralisation, and in particular the origin of sulfur. A collaborative study between Dr Geordie Mark (Monash University), Dr Kathryn Prince (ANSTO), Dr Chris Ryan (CSIRO) and Dr Patrick Williams (James Cook University) has used Secondary Ion Mass Spectrometry (SIMS) and Proton Induced X-ray Emission (PIXE) to examine the correlation between mineral composition and growth history to unravel the hydrothermal processes associated with ore formation together with constraining the origin of the main ore-forming components.

Preliminary results show that pyrite grains exhibit significant and repeated micron-scale fluctuations in trace element chemistry, and that individual trace elements, for example arsenic (As) and cobalt (Co), record distinctly different distributions. This suggests highly variable fluid-mineral element partitioning during ore formation.

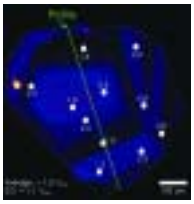
These geochemical associations are attributed to a combination of competing processes:

- fluctuations in hydrothermal fluid chemistry;
- differential element diffusion; and
- variation in fluid-mineral trace element partitioning.

These trace element fluctuations, however, do not correlate to d34S, where isotopic variation was minimal and on the scale of instrument precision: thus suggesting that while fluid mixing is consistent with the deposition of Cu-Au mineralisation a single dominant source for sulfur is likely.



PIXE-generated geochemical profile across a pyrite grain (see left for location) showing a de-coupled distribution between Fe, As and Co.

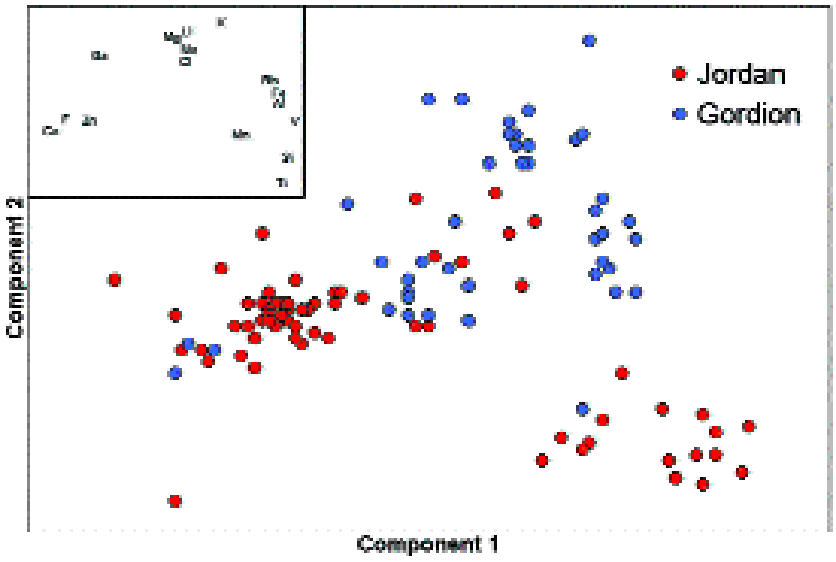


Zoned pyrite grain from the Ernest Henry Cu-Au ore body showing significant and repeated fluctuations in arsenic. Points refer to the location of individual SIMS $\delta^{34}S$ analyses (results

^{14}C AMS dates Ancient Angkor Civilisation

For well over five centuries, the Khmer kingdom ruled over a vast territory, including most of what is now known as Cambodia, Thailand, Vietnam and Laos. Between the 9th and 14th century AD, the Khmer Kings developed the Angkor area into a remarkable administrative and religious centre for their society. According to new estimates by the Greater Angkor Project, the entire urban complex of the capital city covered an area of about a 1000 square kilometres making it probably the largest archaeological site in the world. Great stone temples and some other monumental structures and earthworks are the only visible remains of this fascinating civilisation. Thankfully, there is a substantial on-going multinational effort to preserve and restore what is left and in 1992 UNESCO (United Nations Educational Scientific and Cultural Organisation) declared Angkor as a World Heritage Site. As part of the Greater Angkor Project, Dr Mike Barbetti (NWG Macintosh Centre for Quaternary Dating, University of Sydney), Dr Roland Fletcher (Department of Archaeology, University of Sydney), Drs Ugo Zoppi and Quan Hua (ANSTO), along with R.K. Chhem (Faculty of Medicine, National University of Singapore), C. Pottier (École Française d'Extrême-Orient Siem Reap, Phnom Penh, Cambodia), and M. Watanasak (Faculty of Environment and Resource Studies, Mahidol University, Thailand) used radiocarbon dating by AMS to establish that the remarkable urban design of the royal terraces was adopted in Angkor as early as the 10th century AD. Furthermore, they established that the origin of the Prei Khmeng burials was placed in a period much earlier than the first phase of Hinduisation.

Archaeological excavations carried out by EFEO in collaboration with the Cambodian authority led, in January 2001, to the discovery of a human skeleton (see figure above right) at Prei Khmeng, the site of one of the oldest known Khmer shrines in the Angkor region. A second excavation campaign in May and June 2001 unearthed six more skeletons, demonstrating the existence of a real necropolis. The discovery of these burial places is particularly interesting because this kind of disposal of the dead differs from the procedures normally used during the Angkor period. Knowing how much older these tombs are compared to the temple will offer the first direct behavioural insight relating to the Hinduisation of the Khmer cultural world, a crucial point in its formation.



Principal Components Plot of the PIXE-PIGE results for the combined archaeological datasets for Hellenistic and Roman ceramics from Jordan and Gordion in central Turkey. Note the occurrence of the Gordion samples within larger clusters from Jordan suggesting a Levant source for these wares. Less certain are the interclustering of

A New Perspective on Hellenistic Trade & Exchange in the Western Mediterranean

Two archaeological projects conducted through AINSE by researchers at the University of New England have produced an unexpected insight into long-distance trade during the Hellenistic and Roman periods. Dr Pam Watson employed PIXE-PIGE analysis on ceramics from an archaeological survey in Jordan; Dr Peter Grave was also conducting a similar analysis on ceramics from Hellenistic/Roman Gordion, in Central Turkey (see map inset).

Techniques such as PIXE-PIGE are very useful in defining compositional types and for distinguishing local from non-local archaeological ceramics. In this case, while long-distance links are well known for the period, the two researchers were surprised to find not one but several shared types between their study regions. "What is exciting about the outcomes of these pilot projects is that we now have a solid basis for undertaking a more detailed collaborative program of research to determine likely production centres and the dynamics of trade during this period" said Dr Grave.

Research Highlights

Environmental Science

Macquarie Marshes - Geomorphic Model

The Macquarie Marshes in north-west NSW is one of several wet land areas in the Murray Darling Basin.

Marshes are an important habitat for migratory birds and other species and a key aspect of their management are the creek systems within them. In order to understand the causes of avulsion (the movement of channels) and the role of near-channel sedimentation in an inland fluvial wetland system, Dr Paul Hesse and his AINSE Postgraduate scholar Tim Ralph at Macquarie University in collaboration with Dr Henk Heijnis at ANSTO use lead-210 and AMS carbon-14 dating in conjunction with sedimentological analysis to document the rate and distribution of sedimentation adjacent to a marsh feeder channel in the southern Macquarie Marshes.

Recent sedimentation has lead to the formation of contemporary levees along the channel margin. Avulsion in this system is therefore related to extensive vegetation-induced in-channel and overbank deposition resulting in the formation of an alluvial ridge. This elevates the channel belt above the surrounding floodplain, thereby creating a gradient advantage and providing favourable conditions for avulsion and subsequent channel abandonment.

Differences between the contemporary and long-term sedimentation rates, with historical evidence, indicate a recent change in sedimentation regime, which is related to channel avulsion at this site 70 to 90 years ago rather than to catchment-scale post-European influences. This research provides a model for the contemporary geomorphic behaviour of a significant floodplain wetland system in south-eastern Australia.

Top: Sectioning sediment core into 1cm slices.
Bottom: Salt marsh habitats in the lower estuary reaches of the Pitt Water estuary.

Damned dams

Pitt Water estuary in Tasmania is an important wetland area containing significant waterfowl habitat, feeding grounds of migratory waders and several species of flora and fauna that are listed on the Tasmanian threatened species list. The estuary was designated as a Ramsar site in 1983. Ms Iona Mitchell (Tasmanian Aquaculture and Fisheries Institute), Associate Professor Andrew McMinn (IASOS) and Dr Henk Heijnis (ANSTO) are attempting to link historical information to sedimentary profiles in order to identify the sequence and consequence of major changes that have occurred in the estuary.

The changes have mostly been driven by human activity in the catchment. Especially significant are changes in the water flow regime which are reflected in sediment cores taken from the estuary. The degree of siltation and the change in sediment composition is determined from particle size analyses, while changes in the nutrient and salinity regime of the estuary are being assessed from the analysis of preserved diatoms. A chronological record of these changes has been obtained using 210-lead dating of sediment samples by the ANSTO radiochemistry laboratory.

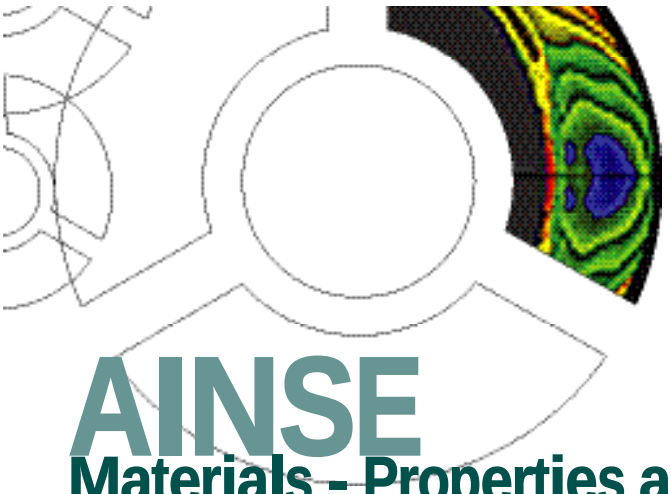
Preliminary results show that the construction of irrigation dams has produced a significant change in the sedimentary processes in the estuary. There has been a reduction in sedimentation rate and deposition of finer sediments, which could impact on the biological and geochemical functioning of the estuary.

Bacteria clean up polluted water

Associate Professor David Parry and AINSE Postgraduate Scholar Tony Jong have been working on a relatively novel approach to remediating water quality in mildly acidic metal and sulfate contaminated water.

They have demonstrated microbial sulfate reduction and subsequent precipitation of copper (Cu), zinc (Zn), nickel (Ni), iron (Fe) and arsenic (As) by a mixed population of sulfate reducing bacteria (SRB) in an upflow anaerobic packed bed reactor containing silica sand. After an initial lag phase, the activity of SRB increased the water pH from about 4.5 to 7.0, and removed about 80% of the sulfate after a 14 day treatment period. Metal removal efficiencies of more than 97.5% for Cu, Zn and Ni, greater than 82% for Fe and greater than 77.5% for As were achieved, while no magnesium (Mg) or aluminium (Al) were removed.

Adsorption is one of the processes that affects the bioavailability and mobility of metals in the environment. A series of batch adsorption studies were conducted on the bioreactor metal sulfide solid phase in 100mL vessels. The results from adsorption experiments indicate that microbially-produced metal sulfide adsorbent has a high uptake for a wide range of metal ions (Ni, Cu, Fe, Zn, Pb and As), and the residual levels to which the concentration of the ions is reduced is very low, in the case of Pb being as low as 90 $\mu g\ L^{-1}$. The adsorption isotherms were characterised by an initial rapid uptake of the metal by the adsorbent, with equilibrium reached after only 72 hours. Epirez® resin embedded samples of the adsorbent immobilised on sand were analysed at ANSTO using secondary ion mass spectrometry. Cu, Zn, Ni, Fe, As and sulfur were detected, suggesting that formation of insoluble metal sulfides in addition to adsorption processes are responsible for the decrease in dissolved metals in the bioreactor. These results have important implications to the management of metal sulfide sludge immobilised through microbial sulfate reduction, since adsorbed metals can be easily remobilised.

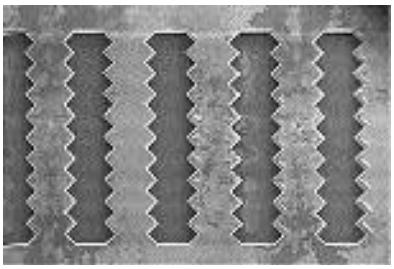


AINSE
Materials - Properties and Engineering

Harder and smaller

Micro-replication has been one of the important steps in the manufacturing of microsystems for commercial applications. The applications of microsystems have so far been driven by their advantage in terms of low cost and high volume production. Recently, increasing use of polymeric based microsystems for biotechnology and bioanalysis applications has further necessitated the need to accelerate the development of production technologies. Microembossing and microinjection moulding are realised to have a great potential and are seriously pursued for this purpose.

Dr Muralidur Ghantasala at Swinburne University has been working on extending the life of microembossing tools. A typical embossed structure is shown in the figure to the right (the feature width in this picture is approximately 150mm). His studies have shown that life of a shim could vary from 10,000 to 100,000 cycles depending on the feature size and structure. Two different approaches were used in these investigations. In the first method, shims were electroformed using different bath formulations. The second approach sought to increase the lifetime of these shims through the application of wear resistant coatings.



Typical microembossed structure on polycarbonate substrate using electroformed nickel shim

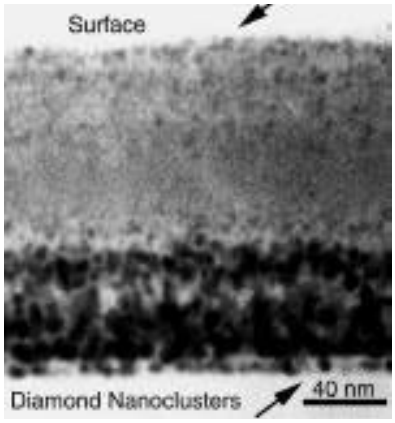
Initially shims were prepared following two different bath formulations. Structure and microhardness of the shims prepared in both the plating baths were investigated. Following the second approach, wear resistant coatings (TiN and CrN) deposited on the electroformed shims were characterised. The RBS, XRD and nanoindentation facilities at ANSTO were used to study the composition, structure and hardness of the shims (in both formulations) before and after depositing TiN and CrN films.

These studies showed that the structure and microstructure of the shims have a profound effect on the grain size and structure of these films. A detailed analysis of the films on the shims is in progress. Films on silicon substrates were used to optimise the composition and structure of these coatings. TiN and CrN films were deposited using an arc deposition technique in partially and fully filtered conditions and at different substrate temperatures ranging from room temperature to 300°C. TiN films deposited at room temperature showed a strong (111) orientation. At higher temperatures there is a clear deviation from (111) orientation in these films. The film texture and grain size have also been found to be a function of substrate temperature. These changes seem to have contributed to the reduction of stress in the TiN films deposited at higher temperatures. Films were stoichiometric at all the substrate temperatures investigated in this study. In comparison, fully filtered films at 300°C showed a very marginal crystalline character (as indicated by a very low intensity broad peaks in the XRD analysis) and have fewer macroparticles, as expected. However, these films appear to have been more stressed compared to the partially filtered films deposited under the same conditions. Evaluation of film stress using XRD and the determination of microhardness of these films are in progress.

Diamond AIchemy

For centuries scientists have been fascinated by the 'alchemy' of transforming carbon into diamond. Under atmospheric pressure, graphite and not diamond is the stable form of carbon. This project aims to fabricate diamond nanocrystals embedded in a glass matrix by direct ion implantation followed by thermal annealing. Unlike other methods of making diamond, the coalescence of carbon into diamond occurs under heating in a conventional furnace and does not require the application of high external pressures or any pre-existing diamond template. Professor Steven Prawer and his team at The University of Melbourne has developed a scheme to create arrays of these nanocrystals for use in quantum devices.

They have already demonstrated the success of the technique for making diamond in this way (see figures right). However, the mechanism by which diamond forms remains a mystery. They suspect that hydrogen is implicated in the mechanism because samples annealed in the absence of hydrogen do not form nanodiamond. SIMS was used to provide depth profiles of C, O, Si and H in the fused quartz matrix and in so doing elucidate the mechanism of diamond formation.

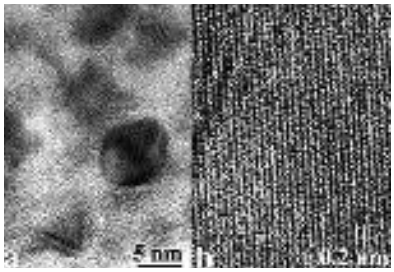


Diamond Nanoclusters in a fused silica matrix created by carbon ion implantation

Crafty RAFT

More and more applications are being developed for plastics, which are formed when some sort of radiation is applied to the monomers. Most people who have been to the dentist in the last few years will have experienced polymer fillings which are hardened or cured using visible blue light. Plastic lenses are hardened by thermally induced polymerisation. Some coatings are hardened by high energy ionising radiation.

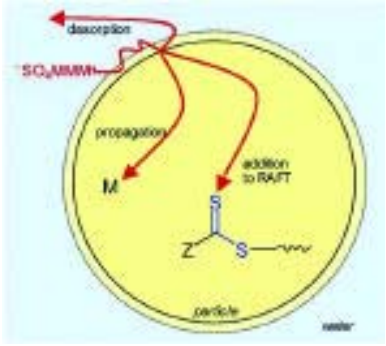
AINSE funded gamma irradiation facilities at Lucas Heights are being used by Stuart Prescott of the Key Centre for Polymer Colloids (KCPC) at the University of Sydney to give even more control to the eventual properties of polymers. They have been studying the chemical mechanisms of the Reversible Addition Fragmentation chain Transfer Polymerisation (RAFT) processes. The use of RAFT technology allows unprecedented control of the molecular architecture of the polymer chains, including narrowly distributed molecular weights and more complex architectures such as A-B-A blocks and star polymers. Commonly used RAFT agents like diothioesters have been widely studied but there remains debate over the details of their action, with particular difficulties arising in heterogeneous systems such as emulsion polymerisation.



TEM image of a small number of diamond nanocrystals in the silica matrix. Note the octahedral habit. The lattice image shows the internal structure of one of the dots. The lattice spacing corresponds to the (111) lattice planes of crystalline diamond

RAFT-mediated polymerisation can be initiated by gamma radiation, which works well in homogeneous systems where the RAFT agent is dissolved in the monomer. In emulsion systems, where the monomer is dispersed in an aqueous solution, there is an unexpected decrease in the rate of polymerisation as the amount of RAFT agent is increased.

Kinetic investigations of styrene polymerisations have been carried out using the dilatometric equipment that the KCPC has installed at Lucas Heights. The polymerisation rates in-source and out-of-source are slower for the RAFT-containing system than for the non-RAFT system. Moreover, the relaxation from the in-source rate to the out-of-source rate is faster. With these results a mechanistic understanding of heterogeneous RAFT polymerisations is developing, focussing on phase-transfer events for the radical species involved. We can now conclude that radical transfer between the dispersed and continuous phases in the emulsion system may explain many of the observed problems. With this knowledge, it is possible to design RAFT agents that have considerably better performance in emulsion polymerisation reactions.



AINSE
Materials - Structures and Dynamics

LONGPOL sheds new light on crystal field spectrum.

The LONG wavelength neutron POLarisation analysis diffractometer-spectrometer at HIFAR has been upgraded over the past five or more years. Apart from new software the instrument has been made more sensitive by the installation of locally designed compact polarising supermirrors.

Neutrons respond to small energy changes in materials resulting from lattice or magnetic excitations. The energy change in the sample is given to or taken from the energy of the neutron and the neutron's final energy can be measured by its time of flight from sample to detector.

One source of energy change is that associated with magnetic atoms subject to the electric field from surrounding atoms. The energy levels of the atoms are separated by this electric field and the energy of transitions between them can be measured by neutron spectroscopy. Unfortunately in an experiment without neutron polarisation analysis the magnetic transitions cannot be distinguished from normal lattice vibrations.

Figure 1 shows a spectrum on $CeCu_6$ recently measured by Dr Trevor Hicks of Monash University. Ce is the magnetic ion in which transitions between crystal field levels should be able to be measured. Because of polarisation analysis LONGPOL can measure the difference between the magnetic spectrum and that coming from lattice vibrations. Normal neutron spectroscopy measures the sum of these.

Figure 2 shows a similar spectrum from the same material measured on instrument IN6 at the Institut Laue-Langevin, Grenoble, France . The same features are there in the spectrum except that they are superimposed. Walter et al ascribe the large wings in the scattering around zero energy transfer to a magnetic transition centred close to zero energy. They also point out some crystal field transitions at about an energy transfer of -6meV. Comparison with figure 1 shows that this cannot be right. The wings around zero energy transfer are negative going in the LONGPOL spectrum whereas the supposed crystal field transitions at about -6meV are positive going. Our tentative conclusion is that the feature at -6meV is due to lattice vibrations and the wings at zero are in fact due to magnetic transitions. This will need to be confirmed by experiments that switch the neutron polarisation direction at the sample to definitively separate magnetic transitions and lattice vibrations.

It is indeed gratifying that LONGPOL produces a spectrum, which is comparable to that from one of the best neutron spectrometers in the world. LONGPOL incorporates a method of statistical chopping which transmits up to 50 times the intensity of instruments like IN6. For selected types of spectra this method is very effective. The resolution of LONGPOL is inferior to that of IN6 but we are already implementing software that can deconvolute most of the experimental broadening from the spectrum. In some spectra we have achieved an energy resolution of 20meV at close to zero energy transfer.

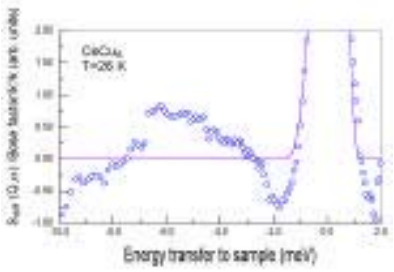


Figure 1. Neutron spectrum from $CeCu_6$ measured on LONGPOL. Note that the spectrum is of the difference in lattice and magnetic scattering.

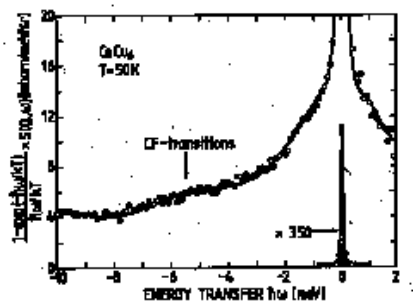
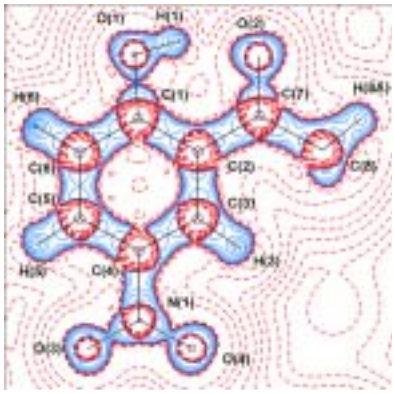


Figure 2. The spectrum of $CeCu_6$ measured on IN6[1]. Note that the spectrum is of the sum of magnetic and lattice scattering.

Charge Densities, Hydrogen Bonding and Drug Design

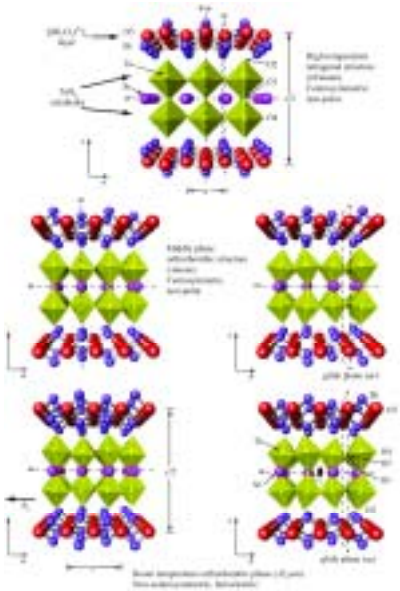
The hydrogen bond is responsible for molecular aggregation, protein folding and enzyme activity. Conventionally strong hydrogen bonds such as O – H ···O, N – H ···O and O – H ···N have been extensively studied in the areas of supramolecular chemistry, crystal engineering and have important roles in nature. For example, the gross structure of protein molecules, the structures of the genetically important DNA and RNA molecules, as well as drug-receptor binding.

Most pharmaceuticals act by interacting with specific macromolecular receptors, located inside or on the surfaces of cells. The drug-receptor interaction is extremely specific in a stereochemical sense (drugs having a particular shape), being influenced by the distribution of functional groups as well as the absolute configuration of the molecule. The interaction is also specific in an electronic sense, in that the charge distribution must be entirely complementary to that of the receptor binding site. A detailed knowledge of the drug-receptor interactions allows investigators not only to know how and why a drug acts, but also to develop new drugs that are more potent, more selective and have far less unwanted side effects. Recent developments in crystallography and high-performance computing make possible the determination of experimental charge densities on a reasonable time-scale. Consequently, it is now feasible to carry out structure/activity correlations with this final and critical piece of information included.



The negative Laplacian of the electron density of 1-(2-hydroxy-5-nitro-phenyl)-ethanone as determined from the multipole model. Electron density contributions from lone pair, covalent and hydrogen bond electrons are clearly discernible.

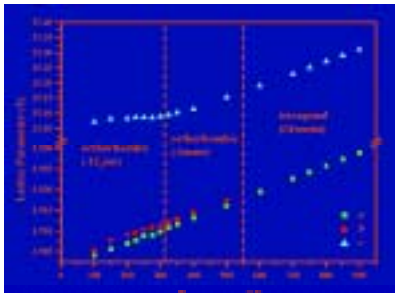
Drs David Hibbs and Jacob Overgaard of the University of Sydney, together with Dr Ross Piltz from ANSTO, have determined the experimental charge distribution in a number of potential drug molecules using a combined high-resolution neutron and x-ray single crystal diffraction technique. In this approach single crystal neutron diffraction is used to obtain the exact location of all atomic nuclei, including any hydrogen atoms, resulting in a highly accurate molecular structure which is of vital importance in the study of hydrogen bonding and the charge distribution. High-resolution x-ray diffraction data can then be incorporated into a so-called 'multipole' model of the crystalline electron density. From this model, the topology of the electron density can be examined at its most salient point, close to the atomic nuclei, with features as close together as 0.4 x 10^{-10}m being measurable (see diagram top right). Once the charge distribution has been determined, various chemical and physical properties that depend on the distribution can be derived and, because the strength and nature of any interactions are characterised by the topology, the chemistry of the molecule can be recovered as a property of the charge distribution.



Ferroelectric fun

Layered bismuth oxides such as $SrBi_2Ta_2O_9$ (SBT) are of considerable interest for use in the next generation of ferroelectric devices. A major stumbling block to their use is the degradation of the performance of thin films of SBT when they are annealed above the Curie Temperature (Tc), as occurs during their manufacture. Changes in the structure of SBT as it goes from the room temperature ferroelectric state to the high temperature paraelectric phase are thought to be important in this.

A/Professor Brendan Kennedy from Sydney University and Rene Macquart have used high-resolution powder neutron diffraction methods to probe the structural changes in SBT as a function of temperature. These measurements have shown the presence of a hitherto unidentified intermediate phase in SBT at elevated temperatures, solving a fifty-year dilemma on the relationship between the ferroelectric properties and structure. Combining the neutron diffraction results with group theory, the structure of the three phases was determined. The ferroelectric properties of SBT arise from displacement of Ta atoms from the center of the TaO_6 octahedra. At the same time, the TaO_6 octahedra rotate with respect to each other lowering the symmetry from tetragonal to orthorhombic. These two movements are independent of each other. Near the critical temperature, Tc, Ta atoms move to the center of the TaO_6 octahedra, however, the TaO_6 rotations persist. The structure of the intermediate phase is thus paraelectric but not orthorhombic. Further heating of the sample removes the rotations the TaO_6 groups and



Research Highlights

Biomedical Science and Biotechnology

Radiopharmaceuticals and Imaging

The rapid advances in imaging technology and the development of modern "physiological radiotracers" has, for the first time, enabled scientists and clinicians to make a non-invasive study of the biochemical processes leading to diseases in the body with unprecedented resolution and sensitivity. This capability has largely been possible through the development of the functional imaging modalities Single Photon Emission tomography (SPECT) and Positron Emission Tomography (PET). By employing a range of medium to short lived radionuclides, various metabolic tracers have been used to study, image and define diseases at the molecular level in neuroscience, oncology and cardiology. For example, tracers radiolabelled with carbon-11, fluorine-18 or iodine-123 have allowed the study of neurological disorders such as epilepsy, Alzheimer's and Parkinson's disease using PET and SPECT.

During the past two decades receptor ligands and drugs from the pharmaceutical industry have been investigated as potential radiopharmaceuticals for detecting and monitoring neurological and psychiatric disorders. One such drug is the antipsychotic drug Dexetimide that, after radiolabelling with the SPECT isotope iodine-123, becomes a potent and selective receptor marker for the muscarinic acetyl choline receptor (mAChR) system. Diseases such as Alzheimer's disease (AD), epilepsy and a wide range of related disorders have been linked to abnormalities in these mAChRs.

AINSE is currently supporting four clinical trials involved in cognitive impairment in dementia patients and in AD, in epilepsy and in post-traumatic stress disorder.

At the Austin Repatriation Medical Centre (ARMC), Dr Chris Rowe and team are investigating the utility of this radiopharmaceutical in determining the cognitive response in AD patients that may be subjected to chronic drug treatment using acetylcholine-esterase inhibitors (AChE). This work will enable researchers to compare the relative potency of various oral AChEs. It will also help to establish dose responses and compare the effectiveness of these and other similar drugs such as nicotinic agonists in treatment. Finally ^{123}IDEX SPECT may allow the quantification of the functional integrity of cholinergic neurones in humans.

Dr Rowe is also using IDEX to image epilepsy patients. Surgical resection of the seizure focus is an effective treatment for focal epilepsy that cannot be controlled by medication. The success rate of surgery depends upon the degree to which the focus is accurately localised. When MRI demonstrates a lesion that is subsequently proven to be the seizure focus, cure rates of 80-90% are obtained. However, if localisation of the focus is based on EEG or other investigations such as PET and SPECT when MRI is normal or inconclusive, the success rate falls to 40-50%. In an earlier collaborative study by Dr Rowe and Dr Andrew Katsifis at ANSTO, it was demonstrated that reduced muscarinic neuroreceptor binding of ^{123}IDEX was seen with SPECT at the seizure focus in 25 patients with temporal

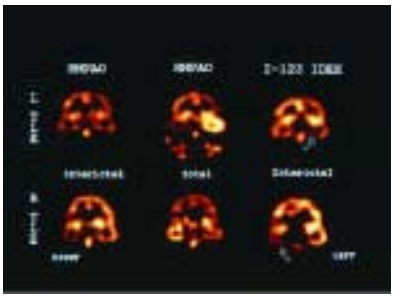


Fig 1. A study of an epilepsy patient with [^{123}]IDEX compared to a conventional ^{99m}Tc-HMPAO Ictal study. HMPAO shows enhanced perfusion only during seizure (middle top) whilst IDEX shows reduced mAChR density.

lobe epilepsy. In four of five cases with normal or inconclusive MRI, a focal reduction in ^{123}IDEX binding was detected. Therefore, an important clinical role for ^{123}IDEX SPECT could be the accurate determination of epileptic foci in patients with normal or inconclusive MRI scans.

In another study Dr Rey Casse and Ms Elizabeth Goble from the Queen Elizabeth Hospital in South Australia, are using ^{123}IDEX SPECT to investigate if there are reductions in mAChR levels in patients with post traumatic stress disorder (PTSD). PTSD is potentially a highly significant health concern with a high clinical and social demand for better treatments. PTSD has been shown to have a significant impact on workers with high rates of working days lost. PTSD has also been shown to have important dysfunctions of working memory. IDEX SPECT is therefore used in a concurrent clinical trial involving the prescription of Donepezil, an

acetylcholinesterase inhibitor (a drug which is hypothesised to improve the working memory deficits in PTSD) to evaluate whether this can lead to a decrease in general post traumatic symptomatolgy.

In a fourth study, Dr Casse and Dr Karyn Boundy are using this radiopharmaceutical to study patients with mild cognitive impairment (often the precursor to AD) to confirm whether there are any reductions in acetylcholine receptors present in the medial temporal lobe and cingulate gyrus with ^{123}IDEX. This will have important social ramifications if IDEX SPECT can be used to distinguish patients with mild cognitive impairment likely to proceed to AD from normal elderly subjects.

A reliable diagnostic marker for predicting AD in its early stages would be of great benefit to patients, their families and the community. Early intervention with drug treatment with drugs that appear to halt the progress of Alzheimer's Disease has led to great interest in the earliest possible detection. At present, there is no genetic test or biological marker that can reliably predict the person with subjective memory complaint will evolve into AD. Current regulations require that a relentless decline in cognitive function be observed before intervention with cholinesterase inhibitors is permitted. A procedure to identify persons at risk of Alzheimer's Disease would allow earlier intervention with new and novel preventative approaches with better outcomes. The cholinergic neuronal system is affected in AD and loss of function in this system is the major cause of memory decline. Post mortem studies have shown a dramatic loss of the markers Choline Acetyl-transferase and AChE for the cholinergic neurones in AD particularly in the medial temporal lobe structures such as the hippocampus and the parahippocampal gyrus.

The ^{123}IDEX doses are produced in the R&D laboratories at ANSTO by Dr Andrew Katsifis and colleagues Mr Vahan Papazian and Mr Tim Jackson and transported overnight to the Queen Elizabeth Hospital in Adelaide and the Austin Repatriation Medical Centre in Melbourne. The 13-hour half-life of ^{123}I makes this feasible for distribution around the country.

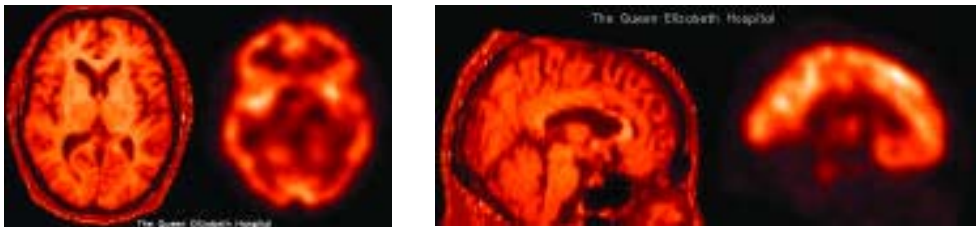
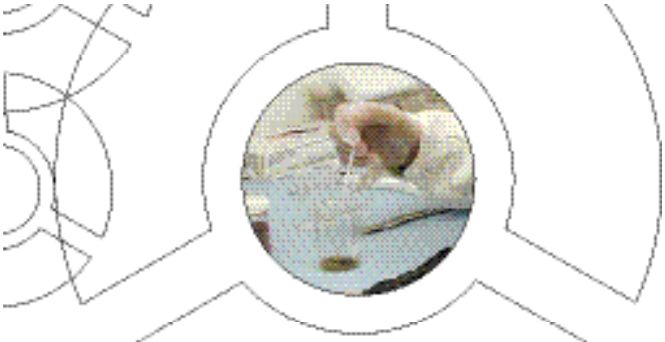


Fig 2 and 3. Coregistration of ^{123}IDEX SPECT and MRI in human brain. These images will be used to compare with patients suffering various neurological and psychiatric disorders



The AINSE Winter School
Nuclear Techniques Applied to Natural Processes

The sixth AINSE Winter School on nuclear techniques applied to natural processes was held at the Lucas Heights Science and Technology Centre from Saturday 6 July to Wednesday 10 July 2002 with a great deal of input from ANSTO and university staff.

Introduction

The Winter School was held over a five-day period, from Saturday to Wednesday. Thirty-seven students participated in the Winter School; they had the following majors 3 biology, 2 biomedical Science, 12 chemistry, 3 engineering, 3 environmental science, 3 geology, 1 health sciences, 2 nuclear medicine technology and 8 physics.

A background lecture and experimental session was provided for each of the following topics:

- Neutron Scattering
- Ion Beam Experiments
- Natural Radioactivity
- Radioactivity and the Living World
- Radiation Chemistry

Monday Evening Presentation

This year Pam Keenan, head of ANSTO Communications Group, was invited to speak. Her presentation was entitled *Media Miss-Information*. In this address she presented some of the challenges involved in getting correct and timely information out through the media. The presentation generated a great deal of interest in the students and questions continued well after the presentation.

Khu Vu, Monash University

Shannon Orbons, Flinders University

Student Comments

Excellent job!

Overall a TOP experience for which I am very grateful

I was especially impressed by the atmosphere and friendliness of the staff at AINSE

A lot of fun but very hard work

The demonstrators were good at simplifying details and were very patient and approachable

I had an excellent time. The people were wonderful and helpful and I would recommend it to others.

A great School that was stimulating at an intellectual and social level

My expectations were met or exceeded. Thank you for giving me the opportunity – maximum kudos to all involved

I found the neutron scattering session the only one were I learnt anything useful (electronic engineering student). [A student in the same discipline made a similar comment last year]

I particularly enjoyed the variety of disciplines we were exposed to – an eye-opening experience

I never thought I would understand ion-beam analysis and how it can be applied to environmental studies

Impressed with how we were "taken care of"

Krystina Saunders, University of Tasmania

David Bray, The University of Sydney

Thanks

AINSE is indebted to Professor Helen Garnett, 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, David Sangster and Ken Doolan from the universities involved in the planning and implementation of this year's Winter School.

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.

Amy Culverson, Charles Sturt University

Jeremy Robinson, Queensland University of

2002 Conferences and Workshops

There were 639 participants at the conferences and 167 at the workshop/symposia. 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.

The focus this year has, once again, been well and truly on neutrons, with two major workshops held towards the end of the year.

Environmental Radioactivity: Migration, Measuring and Monitoring in the South Pacific – May 2002
The South Pacific Environmental Radioactivity Association - SPERA 2002 conference was held on 13-17 May 2002. There were 80 participants including 39 from ANSTO, 18 from overseas and 4 students; 55 papers and 15 posters were presented.

19th AINSE Nuclear & Particle Physics Conference – July 2002
The 19th AINSE conference on Nuclear and Particle Physics was held on 7–11 July 2002 in collaboration with 15th National Congress of Australian Institute of Physics, *Physics and Industry Working Together*, Sydney Convention and Exhibition Centre, Darling Harbour. There were 313 participants. The Nuclear and Particle Physics Conference section included 7 participants from ANSTO and 11 students. 34 papers and 13 posters were presented. Traditionally one medal is awarded for the best student oral presentation. On this occasion the panel was unable to decide between two exceptional talks and, as their subject matter was very different, it was decided to award two prizes, one to Rachel Butt, from The Australian National University and the other to Ross Young, from The University of Adelaide.

24th AINSE Plasma Conference – July 2002
The 24th AINSE Plasma conference in association with the 11th International Congress on Plasma Physics, ICPP 2002 was held on 15-19 July 2002 at Manly Pacific Parkroyal Hotel. There were 326 participants including 1 from ANSTO, 271 from overseas and 19 students, 97 papers and 380 posters were presented.

Workshop on Neutrons for Engineering at Australia's Replacement Research Reactor - September 2002
The 8th workshop to discuss the neutron-beam instrumentation for Australia's Replacement Research Reactor was held on 16 and 17 September 2002, at the School of Mechanical and Manufacturing Engineering, The University of New South Wales. There were 47 participants including 20 from ANSTO and 8 from overseas; 12 papers were presented.

Neutron-beam Applications to Earth Sciences – December 2002
This workshop was held on 12 and 13 December 2002, Lucas Heights. There were 40 participants including 12 from ANSTO, 3 from overseas and 3 students; 13 papers were presented.