CSEM: ANU's Centre for Science and Engineering of Materials

Materials Monthly

Making materials matter November 2001

Synchrotron

it to me baby

For years materials scientists and engineers have been urging the government to invest in a synchrotron – an advanced piece of materials-research infrastructure costing between $150-200 million – but with little success.

Now, in the space of a couple of months, there have been two significant announcements of major investments in synchrotron research that should see Australia consolidate and extend its reputation in this important field.

A synchrotron is a large, circular electron accelerator that produces intense electromagnetic radiation over a broad energy spectrum that is perfect for probing the basic structure of matter at an atomic and molecular scale. The photon flux from a synchrotron exceeds that from a conventional X-ray tube by a factor of 10^{10} and is like comparing a high powered spotlight with a candle. The synchrotrons many uses include analysing the 3D structure of proteins, designing new drugs, monitoring chemical reactions in real time, characterising advanced materials and inscribing microelectronic circuits that are only dozens of atoms wide.

There are about 80 synchrotrons worldwide. Australia is the largest OECD country without one, and to access overseas facilities the Federal Government has been providing $2 million each year to the Australian Synchrotron Research Program (ASRP) to enable Australian researchers to travel overseas to utilise and develop experimental equipment at these facilities. This is far from a satisfactory arrangement, often lacking flexibility and availability. Many researchers believe that if Australia is to play a significant role in the biological and technological revolution that is sweeping the planet we must invest in our own synchrotron.

After years of lobbying it seems the message may have got through. In June, the Victorian Government announced it would join with Monash University and other project partners to construct a $157 million national synchrotron facility at Monash University.

In August, the Commonwealth Government announced a $14.8 million grant to the ASRP to guarantee Australian researchers continued access to state-of-the-art synchrotron facilities overseas. (The grant was part of the Commonwealth Government's Major National Research Facilities Program.) The injection comes at a critical time as it allows Australia to ramp up its synchrotron expertise during the establishment of the Monash facility (which won't be ready for five years).

Dr Mark Ridgway from RSPhysSE and

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Dr Mark Ridgway with a variety of proposals for synchrotrons in Australia. It's hoped one will be constructed at Monash University in the next 5 years. ▶▶

Inside this MM

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Synchrotron it to me baby

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Prof. J. White from RSC are ASRP committee members and long term campaigners for an Australian synchrotron. Mark was delighted with the Commonwealth Government's announcement, noting "Despite the current lack of a domestic facility, ANU researchers are acknowledged world leaders in several fields of synchrotron-radiation-based science." "The Commonwealth funding is vital to continue our innovative programs, maintain our leadership roles and expand our user base prior to the completion of the national synchrotron at Monash Uni."

"We anticipate that ANU researchers will play a significant role in the design, construction and management of several beamlines at the new national facility," he said.

For more information on the ASRP and synchrotron research, contact Mark Ridgway (Mark.Ridgway@anu.edu.au). The box below presents information on some of the research being done at ANU using synchrotron radiation, and the back cover provides websites with useful synchrotron info.

Materials-based synchrotron research at ANU

Here is some of the materials research being carried out at ANU that makes use of synchrotron radiation – one of the brightest lights a materials scientist could ever hope to use.

Characterising Semiconductors

A wide range of semiconductor materials are being processed and modified for use in electronic and photonic devices. Researchers are interested in understanding how these semiconductors function and perform following such treatments as molecular beam epitaxy, ion implantation and thermal annealing.

To probe these semiconductor materials at an atomic scale, you need to examine them with intense, tuneable radiation unattainable with a conventional, laboratory-based X-ray source. Synchrotron radiation is perfect for these studies and work has been performed by ANU researchers at facilities including the Photon Factory in Japan and the Stanford Synchrotron Radiation Laboratory in the USA.

The results of this research are enhancing the technological applicability of a variety of advanced materials and processes used in the manufacture of semiconductor devices.

Principal Investigators: Dr Mark Ridgway, Dr Mladen Petravic, Dr Gustavo Azevedo and Dr Sanju Deenapanray (RSPhysSE, ANU)

Understanding thin films

Synchrotron X-ray scattering is allowing chemists to study the structure and dynamics in the growth of thin films on a nanometre space scale over a picosecond time frame. Adsorption, self-assembly at interfaces, emulsions, polymers and the imitation of biomineralisation using template mole-

Only synchrotron radiation could have been used to study the tiny amount of film present at the air/water interface.

Principal Investigators: Prof John White and Dr Philip Reynolds (RSC, ANU)

Determining why composites fail

Polyurethane and a variety of composite materials are found in a range of everyday products such as shoes, tennis racquet frames, golf clubs shafts and automobile components. Studies using synchrotron radiation are allowing materials scientists to study what's happening at a molecular level in these materials when they age or are placed in an aggressive environment (for example, surgical implants made of polyurethane are constantly attacked by body fluids, how does the implant material stand up over time). Specifically, the studies are seeking to identify the origins of failure.

Studies on ABS (acrilonitryl-butadiene-styrene) composite materials have shown that the mechanism of failure due to stress or thermal ageing is quite complex, and varies from situation to situation. To carry out the studies a new microtensometer has been developed for use in Raman microscope and synchrotron radiation studies.

Principal Investigators: Prof Dudley Creagh (Uni of Canberra), Prof Ben-Jar (Uni of Calgary) and Dr Adrian Lowe (FEIT, ANU)

Insights on how ore deposits form

Most of the world's gold and copper ore deposits form around deep sea hydrothermal vents. The metals are dissolved in the super-hot, high pressure water coming out of these vents. As the water cools, the metals precipitate out. If earth scientists understood the precise manner in which this precipitation took place it would provide an important aid to predictive exploration. The key is the speciation of metal complexes in solution at supercritical temperatures. It's possible to study this is by examining inclusions in quartz crystals filled with brine, vapour and precipitates. By re-heating these inclusions to the entrapment temperature they can be used as sample cells for high-temperature spectroscopy. Due to the size (less than 50 microns) and metal concentration (100-1000 ppm) of most inclusions, the best and probably only way to determine speciation is by using a synchrotron radiation with a high flux microbeam capability. Studies using this technique are indicating that pH is the important variable in controlling the vapour phase transport of copper. The work has huge potential to help us understand the deposition of other economically important metals such as gold, silver and zinc.

Principal Investigators: Dr Andrew Berry and Dr John Mavrogenes (RSES, ANU)

Many other materials-based investigations

are being performed by ANU researchers. Of equal importance, are bio-medical and bio-technological studies using synchrotron radiation including the recent structural determination of the beta common receptor using X-ray crystallography. While synchrotron users have typically been physicists, chemists and materials scientists and engineers, biologists now represent the fastest growing user base at synchrotron radiation facilities. The potential impact and significance of synchrotron radiation for bio-medical and bio-technological applications was recently demonstrated by a grant in excess of 100 million pounds from the Welcome Trust towards the construction of the new Diamond synchrotron in England.

RSES technology

The Research School of Earth Sciences (RSES) conducts basic research into the nature and behaviour of the Earth emphasising the sub-disciplines of geophysics and geochemistry. The work of the school covers the broad areas of earth physics, geochemistry, earth materials, environmental processes and ore-systems studies. The School operates a range of state-of-the-art geochronology and geochemistry analytical equipment which are available to external scientists and institutions via the Precise Radiogenic Isotope Services group (PRISE) at 'commercial-in-confidence' or 'collaborative research' rates. Here is a summary of services PRISE offers.

SHRIMP

The Sensitive High Resolution Ion Microprobe (SHRIMP) was invented at RSES. It is used for U-Pb geochronology of zircon, monazite, sphene, perovskite, rutile and baddeleyite. It is also used for sulfur and common Pb isotope analyses, and trace element analyses. SHRIMP is an in situ microanalytical facility. Samples are analysed in rocks or thin sections, or as separated grains, mounted, sectioned and polished to expose their internal structure. Cathodoluminescence (CL) and back scattered SEM images are used to target specific areas within grains. The ion beam leaves only minute evidence of the analysis area. The probe pits are 0.5 to 1µm in depth, with a diameter of between 10 to 30 µm, depending on the spatial resolution required. The sampled volume is orders of magnitude smaller than that required for other isotope and trace element microanalytical methods.

SHRIMP analysis of zircon is used for geochronology

TIMS

RSES has a number of thermal ionisation mass spectrometers (TIMS) available for high quality isotope ratio determinations. TIMS measurements are supported by a purpose built, clean laboratory with specifically designated areas for all levels of classical and non-standard dissolution and chemical extraction procedures. PRISE staff have considerable expertise in microanalytical dissolution techniques.

The Finnigan MAT 261 and the new TRITON multicollector mass spectrometers are used for Sm, Nd, Sr, U, Th and Pb isotopic analyses. Osmium and Th isotopic analyses are carried out using a purpose built instrument. TIMS methodology is long established at RSES.

ICP-MS

Two highly sensitive ICP-MS instruments are in routine operation at RSES for precise concentration measurements of some 40 trace and rare earth elements. Sample dissolution is crucial for meaningful and accurate trace element analyses and a sophisticated, multisample microwave digestion system is dedicated to the ICP-MS laboratory. Specialised techniques have been developed for the analysis of platinum group elements and Au. By preconcentration of these elements on a chelating resin, detection limits better than 0.1 parts per billion in the sample can be achieved.

Laser ICP-MS

An EXCIMER laser system, operating deep in the ultra-violet spectrum at a wavelength of 193nm and capable of ablating silicate, oxide and sulphide phases, is used in tandem with the RSES ICP-MS instruments for precision microsampling and analysis of more than 50 elements. Detection limits scale with the ablation site dimensions, and can be tailored to range from sub ppb levels on large ablation sites (100-200 µm) through to low ppm levels on small sites (10-15 µm). The EXCIMER UV laser ablation system presents a breakthrough in the analysis of those elements which display "volatile" behaviour when more conventional IR and UV laser systems are employed. This extends the application of laser ICP-MS to the quantitative analysis of elements previously difficult to measure, in particular the many sulphide associated "ore metals".

Laser-ablation ICP-MS analysis in progress. The sample cell is on the right.

Multi-Collector ICP-MS

The Neptune Multicollector ICP-MS combines the ability of the Inductively-Coupled Plasma to efficiently ionise most elements, with the precision isotope ratio measurement of a multicollector mass spectrometer. This capability opens the door to the study of isotope systems other than those traditionally used in addressing earth science problems. Additionally, when combined with an Excimer laser microsampling system, as already described, the Neptune MC-ICP-MS enables the study of in situ isotopic systematics of a wide range of elements within a solid sample.

Ar-Ar and K-Ar

The potassium-argon laboratory at the Research School is equipped with automated resistance furnace and laser ablation systems linked to high precision, gas source mass spectrometers. Age determinations can be made on suitable total rock samples as well as separated mineral phases such as hornblende, muscovite, sericite, biotite, and K-feldspar (including adularia).

Electron microprobe analysis

Electron Micro Probe x-ray Analysis (EMPA) has been the reference microanalytical technique in the geosciences since the 1960s. An electron beam excites x-rays in a micrometre sized volume of a polished thin or thick section. The x-ray intensities are measured by Bragg-law moving crystal monochromators and by static energy-dispersive silicon detectors (EDS). Multi-element analyses in the 100ppm - 100% range may be obtained in a few minutes. It is possible to detect 5ppm in favourable circumstances. A new instrument with 4 spectrometers plus EDS plus cathodoluminescence detector and large area (cm^2) mapping capabilities is due for installation in December 2001.

More information?

Contact Mark.Fanning@anu.edu.au or Richard.Armstrong@anu.edu.au or check out the PRISE website at http://rses/prise/index.html

Positions vacant

Australia

Research Fellow/Materials (closes 12/12/01)
RSPhySE, EME, ANU
http://www.anu.edu.au/hr/jobs/academic.html#pse645

Fellow/Snr Fellow/Accelerator, Thermal Ionisation and ICP Mass Spectrometry (closes 30/11/01)
RSPhySE, ANU
http://www.anu.edu.au/hr/jobs/academic.html#PSE560/01

Professional Officer/Aircraft Structures (closes 29/11/01)
DSTO, Melbourne, More info: john.borg@defence.gov.au, www.dsto.defence.gov.au/

Snr Lecturer/Image Analysis, (closes 29/11/01)
Electron Microscope Unit, Sydney Uni
http://www.bull.usyd.edu.au/personnel/FMPro?-db=personnel.fm&-format=jobdetail.html&Ref=A44/002118&-find=

Research Fellow/Geochemical Evol. & Metallogeny of Continents, (closes 6/12/01)
GEMOC, Macquarie Uni
http://www.pers.mq.edu.au/ads/2001/Oct/19101.html

Snr Lecturer/Food Bioprocess Engineering (closes 26/11/01)
Qld Uni, http://www.seek.com.au/users/jobsearch.asp

Snr Lecturer/Smart Design and Manufacturing (closes 14/1/01)
Uni of Southern Qld, http://www.usq.edu.au/personel/EmpContent/Ads&PDs/2001/October%2019/163.htm

Overseas

Research Associate/MEMS (closes 30/11/01)
University of Manchester, UK
http://jobs.ac.uk/jobfiles/IG162.html

Postdoc Research Assistant/Electronic & Optical Properties of PPV, (closes 7/12/01)
Uni of Durham, UK
http://jobs.ac.uk/jobfiles/HL097.html

Researcher/Composite Structures, (closes 17/12/01)
Uni of Bristol, UK
http://www.mrs.org/career_services/classified/ads/korea.html

Postdoc Research Assistant/Electronic Properties of Semiconducting Nanotubes (closes 1/2/02)
University of London, UK
http://jobs.ac.uk/jobfiles/RA718.html

Research Fellowship/Nanotechnology(closes 31/1/02)
Toshiba Research & Development Centre, Japan
http://jobs.ac.uk/jobfiles/RA558.html

Research Fellowship/hydrophobicity of surfaces (closes 30/11/01)
Nottingham Trent University, UK
http://jobs.ac.uk/jobfiles/LF103.html

Professor/Polymer Science, (closes 15/1/02)
Swiss Federal Institute of Technology Lausanne
http://www.mrs.org/career_services/classified/ads/ecole.html

For the Diary

▶ **Workshop -An Introduction to Image Processing** — **15 November, 2001**
ANU Electron Microscope Unit, New Extension Seminar Room, RSBS, ANU
bookings and more information: Meg.Mitchell@rsbs.anu.edu.au

▶ **Workshop on Single-Crystal Diffraction** — **11,12 December 2001**
ANSTO, Lucas Heights, Sydney
see http://www.ansto.gov.au/ansto/neut/workshop5.html

▶ **Workshop on Small-Angle Neutron Scattering** — **13,14 December, 2001**
ANSTO, Lucas Heights, Sydney
see http://www.ansto.gov.au/ansto/neut/workshop6.html

▶ **Basic techniques in light microscopy** — **13,14 December 2001**
ANU Electron Microscope Unit, Joint Seminar Room, RSBS, ANU
bookings and more information: Meg.Mitchell@rsbs.anu.edu.au

▶▶ **ACEM 2002** — **4-8 February, 2002**
17th Australian Conference on Electron Microscopy, Adelaide
see http://www.adelaide.edu.au/CEMMSA/acem17/

▶▶ **World Congress on Particle Technology** — **21-25 July, 2002**
4th World Conference, Sydney
see http://www.wcpt4.com/

Who needs a teraflop?

The Meso-scale Physics group, lead by Prof Stephen Hyde and Dr Mark Knackstedt from Applied Maths are modelling the properties of a 2cm cube of rock for the petroleum industry. Using a home-built X-ray tomography scanner that can resolve the sample down to 2 microns. They're building a 3D model of the rock showing its pore structure which they hope will allow them to characterise and predict its properties.

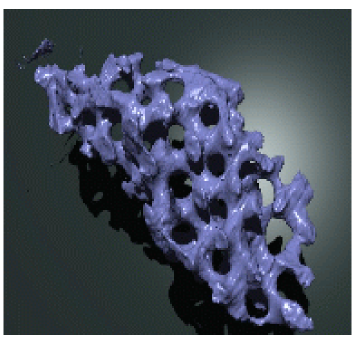
What type of computing power will they need to work with the model? Literally a supercomputer. Scanning the small cube of rock will generate 8 billion 'voxels' (volumated pixels) of data. Reading and writing data sets such as these in and out of memory continually and quickly can only be achieved using enormous computing power.

"Until very recently, doing computations on complex 3D systems such as this has really not been possible," says Knackstedt.

But materials researchers at ANU now have access to the supercomputer operated by the Australian Partnership for Advanced Computing (APAC) – Australia's largest civilian computing facility. By the end of November it's expected to have completed phase 2 of its installation when a total of 120 Compaq ES45 nodes will be connected up to provide a teraflop of processing power.

Applying this awesome computer grunt to problems of ultra fine structure like the rock model is expected to unlock whole new areas of discovery. And rock isn't the only focus of the Meso-scale group with modelling work also being carried out on soil, paper, foam materials, sea urchin exoskeleton, plant tissue and human bone.

Materials scientists from all over Australia are now being encouraged to consider how the new supercomputer might enhance their studies. Have you got a materials problem that a teraflop might help solve?



Modelling the structure of a sea urchin exoskeleton, shown here, is one of many projects needing the grunt of a supercomputer.

More info: *The ANU Supercomputer Facility (http://anusf.anu.edu.au/) is ANU's interface with the Australian Partnership for Advanced Computing (http://www.apac.edu.au/). For more information on the work of Applied Maths on disordered materials, see http://wwwrsphysse.anu.edu.au/appmaths/disord.html.*

Dire Straights

A report just released by the Australian Computer Society has revealed Australia's poor track record in manufacturing information and communication technology (ICT) is getting worse. Last year we imported ICT equipment worth $17.73 billion, more than triple the figure of $5.58 billion in 1990-01. ICT equipment now accounts for about 16% of Australia's total merchandise imports, costing us more than cars and fuel combined. How smart is the clever country?

Materials Grab Bag

Mixing cement and timber

Mixing cement with wood fibre is an effective method for manufacturing low cost, high strength building materials for cheap housing. Rico Cabangon and Kate Semple from ANU Forest Products Technology have been investigating how to improve wood-wool cement board mixes. Recently they presented papers on their work at the International Conference on Forestry and Forest Products in Kuala Lumpur, Malaysia, in October.

Following their presentations they visited Cemboard Berhard, a commercial cement-bonded-particleboard factory to see how wood-cement board could be used. Their product is known as CEMBOARD, and it possesses excellent properties including fire, weather, and termite resistance, and strengths of a minimum of 9 N/sq.mm in MOR and 4500 N/sq.mm in MOE. The boards are used for roof sarking, permanent formwork, fire-rated wall, and flooring. In Malaysia, CEMBOARD is being used for house construction (see photo) as an alternative to timberplank.

Not only is the house built of cement-bonded particleboard, so is the front fence.

CEMBOARD has been used for building construction not only in Malaysia but in other countries such as Singapore, Korea, Hong Kong, Japan, USA, in the middle east and in the Philippines. In Australia, CEMBOARD was used as flooring in the Australian Bureau of Statistics building here in the ACT.

Want to put on a show?

National Science Week (NSWk) aims to focus public attention on the central role science, technology and innovation play in Australia's economic and social well-being. Next year's event will run from 17-25 August, and the Commonwealth Government is offering funding for events running during this period.

The maximum amount available per project is $30,000, and competition for grants is expected to be fierce. Criteria for selection are that projects fulfil the aim of NSWk and reaches a large number of people. Deadlines for submissions is 6 December, 2001.

We all know that materials science and engineering has been the launching pad of whole new industries and markets (think of how materials science has driven IT and communications). We know that, but the rest of the world is often ignorant about the role and value of quality materials research. Well, here's an opportunity for us to put on a song and dance, and spread the word.

If you're interested in finding out more about the NSWk grants, see www.isr.gov.au/science/stap. If you'd like CSEM's assistance to putting a proposal together, please contact us asap.

MM webspotting

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Some good websites on synchrotron radiation.

- ♦ **Australian Synchrotron Research Program**
  http://www.ansto.gov.au/natfac/asrp.html
- ♦ **Advanced Photon Source** (Argonne Nat Lab, USA)
  http://www.aps.anl.gov/aps.php
- ♦ **The Photon Factory** (Tsukuba, Japan)
  http://pfwww.kek.jp/
- ♦ **Stanford Synchrotron Radiation Laboratory**
  http://www-ssrl.slac.stanford.edu/welcome.html
- ♦ **Cornell High Energy Synchrotron Source**
  http://www.chess.cornell.edu/
- ♦♦ **CSEM's fab *Links* Page** can have you at any of these sites with the click of a button: **http://www.anu.edu.au/CSEM/links.html**

Cluster based approaches to salvation and surface chemistry
PROFESSOR MARK GORDON
AMES LABORATORY

venue: **Rm 134**
Research School of Chemistry, ANU
date: **Wednesday, 28 November, 2001**
time: **11am**
More info: **http://rsc.anu.edu.au/RSC/Seminars/thisweek.html**

CSEM

Centre for Science & Engineering of Materials

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Research School of Physical Sciences & Engineering

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Materials Monthly comes out in the first half of each month. We welcome your feedback and contributions. Please send them to David Salt, Editor, *Materials Monthly,* care of CSEM. Please let us know if you wish to be added to our electronic or postal mailing lists.

Electronic copies of *Materials Monthly* can be accessed at: **www.anu.edu.au/CSEM**