ANU Centre for Science and Engineering of Materials

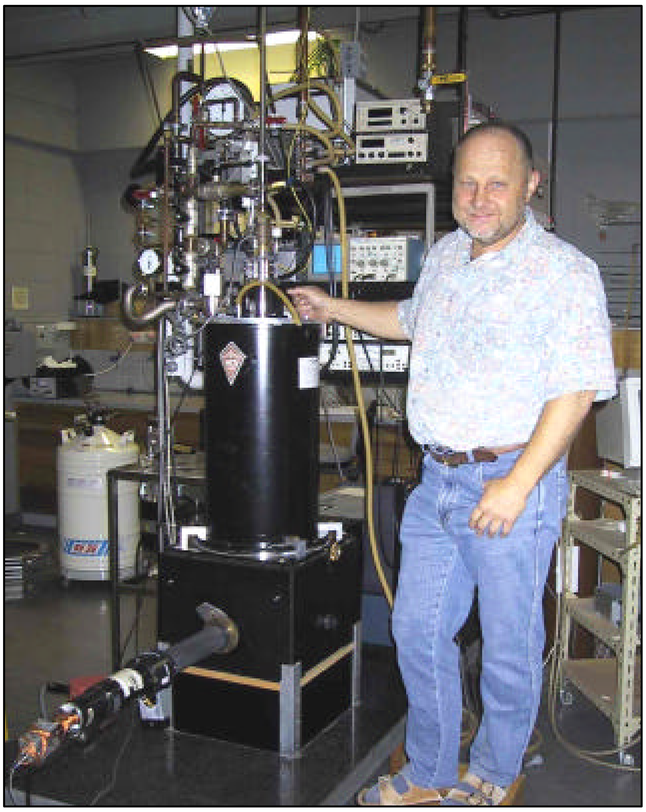
Materials Monthly

Making materials matter — *November 2002*

Tracking the metal of life

Enzymes containing metal ions drive many of the processes that sustain life. These include photosynthesis, nitrogen fixation and the degradation of many metabolites. The metal may only constitute a vanishingly tiny piece of the of the enzyme molecule, which are often massive, but they are usually the active site where the catalytic reaction takes place. Some metalloenzymes, as they're called, can speed up a reaction by a factor of 10^{12}, so understanding this metal component is vital to much biochemistry.

The structural and functional significance of these metal sites, however, is far from easy to unpick given that they make up only a tiny portion of the enzyme protein. Such studies requires a specialised array of sophisticated instrumentation and techniques, as well as the expertise to use them. One instrument particularly suited to their study is the magnetic circular dichroism (MCD) spectrometer. It can optically probe both the paramagnetism and diamagnetism that details the electronic and magnetic properties of the ground states of metal centres.



▲▲ Elmars with an older version of an MCD spectrometer. The next generation device is expected to produce powerful new insights on the nature of metals in metalloenzymes.

MCD spectrometers measure the differential electronic absorption of left and right circularly polarized light in a powerful longitudinal magnetic field. With this information it's possible to determine the oxidation state and spin state of the metal centre and the effects of inhibitors and substrates on the electronic and magnetic properties of the metal centres.

In the past, MCD spectrometers have been used to study the character of a range of ions embedded in crystals, but Professor Elmars Krausz and his team at the Laser and Optical Spectroscopy group, Research School of Chemistry, are now building a new generation of MCD spectrometers designed specifically for the study of metalloenzymes. In October, the group was part of a successful bid for a Linkage-Infrastructure Equipment and Facilities ARC grant to build two Metalloenzyme MCD spectrometers. Both will be built by Elmars' group. One will remain here, while the other will be moved to the University of Queensland. (The University of Sydney was the other partner in the grant.)

These two facilities will be the best instruments of their kind, and will enable researchers at Australian institutions to en-

(Continued on page 2)

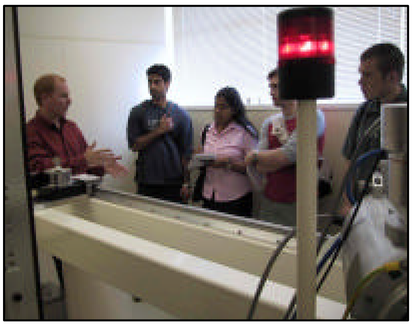
Inside this MM

Volume III, Issue 11

The Technolology of Engineering Materials

Fourth year Engineering students studying Engineering Materials were given tours over three of ANU's top materials characterisation facilities during October.

The tour began at the newly commissioned X-ray Computer Tomography lab at Applied Maths (RSPhysSE) where Tim Senden showed students the magic of being able to probe the internal structure of a range of objects and then modelling that structure with the use of high powered computer reconstructions. [For more details see: http://www.anu.edu.au/CSEM/newsletters/2002/Apr02.pdf (pages 1&3)]



▲▲ In Applied Maths Xray CT Lab

They were then shown over the Metal-Organic Chemical Vapour Deposition (MOCVD) reactor operated by Electronic Materials Engineering (RSPhysSE). Penny Lever described how the facility was used to build opto-electronic devices by coating semiconductors with a variety of thin layers that could might be only a few atoms thick. [For more details see: http://www.anu.edu.au/CSEM/newsletters/2002/Sep02.pdf, (page 3)]

▲▲ Inside the MOCVD

The final stop was the Research School of Chemistry's Laser and Optical Spectroscopy Unit. Elmars Krausz gave the students an eclectic tour of the facility's many lasers and how they are used. Besides learning about the uses of light for probing the properties of matter, the students also discovered a bit about the basic properties of light, lasers and anti-glare polarising screens. [For more details see: http://www.anu.edu.au/CSEM/newsletters/2001/Sept01.pdf, (page 3)]

Many thanks to Tim, Penny and Elmars assisting with the tour.

◀◀ Elmars and the lasers

Tracking the metals of life

(Continued from page 1)
hance the quality of their research and remain internationally competitive through the application of modern MCD spectroscopic techniques to the study of metal-centred biomolecules. They will drive a number of programs in the area of metalloenzyme and photosystem II research.

Some of the features that give the new MCD spectrometers the edge include their ability to take simultaneous absorption readings and their greater range of performance. The magnetic field they will produce will be 8 Tesla, they can operate over a temperature range of 1.3 – 350 K, and take readings over a light spectrum range of 200 nm – 3µm.

Elmars is quick to point out that their developing a system rather than just a spectrometer. The package includes the development of software, hardware and procedures of how to most effectively apply this formidable new technology. The project will get underway in 2003.

More information: Elmars.Krausz@anu.edu.au

Fly-by Phil

A blast from CSEM's past was wandering around campus during early November. Phil Evans, CSEM's past Director, was in town to run a condensed 3rd year Forestry course: Forest Products. During his brief stay, Phil managed to catch up on all the goss, and fill us in on how his directorship of the Centre for Advanced Wood Processing in British Columbia was proceeding. He reckons Canberra and Vancouver are on a par in terms of livability. Both are set in attractive natural surrounds but where Canberra can get a bit hot in summer, Vancouver gets a bit chilly in winter.

▲▲ Phil catches up with Zbigniew (CSEM's current director) over lunch.

Words of substance

"The man who cannot occasionally imagine events and conditions of existence that are contrary to the causal principle as he knows it will never enrich his science by the addition of a new idea."

Max Planck

Rock Physics

Materials Technology

Measuring the material properties of the Earth's mantle

For centuries scientists have been attempting to model the processes that drive and form our planet. That the surface crust of Earth consists of a series of tectonic plates that are constantly moving and being recycled was a major conceptual breakthrough. However, an understanding of how movement in the upper mantle is driving this continental drift has proved frustratingly elusive. This is not an easy place to do science.

▲▲ A sample of mantle rock thrown up by a volcano. To understand how this material behaves in the mantle it needs to be tested under extreme pressure and temperature.

Some rock samples from depths as great as 100 km reach the surface in volcanic magmas, and we also have a comprehensive description of how seismic waves (like sound waves) travel through this region of the Earth. But to truly understand the behaviour of geological materials from the mantle and successfully interpret the seismic data we need a detailed model of the mechanical properties of these materials. And to develop that model it's necessary to test them in conditions equivalent to those found deep inside the planet.

The Rock Physics (Petrophysics) group at the Research School of Earth Sciences is investigating a range of properties of geological materials in conditions that simulate the Earth's mantle. Using two purpose-built test rigs, the Rock Physics group can subject samples of earth materials to pressures of 3000 atmospheres and temperatures of around 1300° C, approximating conditions experienced tens of kilometres deep in the Earth's mantle.

The first test rig uses a gas (argon) charged pressure vessel with an internal electrical heater for the ultrasonic measurement of elastic wave speeds at high temperature. The samples are small cylinders of rock (both natural and synthetic) ranging in size between 7 and 3 mm in diameter.

The use of ultrasonic methods to measure elastic wave speed in rocks is a well known and widely practiced procedure. It involves firing radio-frequency (10-100 MHz) sound pulses through one end of the sample and measuring the interference pattern created as part of the signal bounces back from each end of the specimen. It has been difficult to know how accurately this method simulates seismic waves (at frequencies below 1 Hz) because it's not easy to directly measure seismic waves in rock samples under these high pressure/high temperature conditions. However, direct testing of rock properties at seismic frequencies has been achieved by the Rock Physics group with their 'attenuation apparatus'.

◀◀ Dr Ian Jackson, head of the Rock Physics group, with the first test rig. Seismic wave speeds through samples of earth material are estimated indirectly using ultrasonic interferometery

◀◀ The attenuation apparatus measures seismic wave speed through earth samples by exerting a torsional force on the sample. A technique devised by the group. This test rig is the only one of its kind in the world.

This equipment allows laboratory investigation of the viscoelastic behaviour of earth materials at high temperatures through torsional forced oscillation and microcreep tests. As with the ultrasonic method, small cylindrical samples are heated up electrically in gas-charged pressure vessels. The sample being studied is mounted within a thin-walled iron sleeve between torsion rods of alumina and steel and connected to a standard of known mechanical properties. The combination of sample + standard is then twisted at seismic frequencies. The resulting angular distortions of sample and standard provide data from which the seismic shear wave speed and attenuation can be calculated.

▲▲ The sample is mounted within a thin walled iron sleeve (indicated with the arrow) between torsion rods of alumina and steel.

Results from the attenuation apparatus have allowed researchers to check the validity of the speeds estimated from the ultrasonic studies. There is broad agreement in the results between the two techniques for temperatures below 1200 K, but considerable divergence above this temperature. This suggests that care needs to be exercised when applying the results of ultrasonic estimates at high temperatures. These results have important implications for the interpretation of models of seismic wave speed variability for the upper mantle.

This is just one part of the work being carried out by the Rock Physics group. Other inter-related projects include the creation of a range of synthetic earth materials (such as synthetic polycrystalline specimens of the major upper mantle mineral olivine) to test the systematic variation of material properties with key parameters such as grain size and basaltic melt fraction; and an array of light microscope, TEM and SEM studies of the microstructures of samples. By integrating a knowledge of the macroscopic physical properties of earth materials (such as strength, seismic wave speeds and attenuation) with an understanding of their microstructure the group is providing deep insights on how the Earth's mantle behaves.

More information:
http://rses.anu.edu.au/petrophysics/PetroHome.html

Opportunities

!!!Last Call!!!

◀•▶CSEM Prizes ◀•▶

Attention all undergraduates currently finishing off their final year thesis. Why not enter it for a CSEM Prize.

You could win $2,000! and all you have to do is submit a copy of your thesis to the Director of CSEM by the end of November.

Two awards are on offer:
best thesis in the field of **Science of Materials**, and

best thesis in the field of **Application of Materials.**

Winners will receive a certificate, a cheque for $2,000 and publicity. What a great way to finish off a challenging year.

In order to be eligible for the prizes students must be enrolled in a program leading to the award of a degree of Bachelor offered by ANU.

For the full set of conditions, see
http://www.anu.edu.au/CSEM/Prizes.htm

But remember, the closing date for submissions is

30 November, 2002.

◀•▶CSEM Prizes ◀•▶

Australian Sychrotron

A workshop for potential users

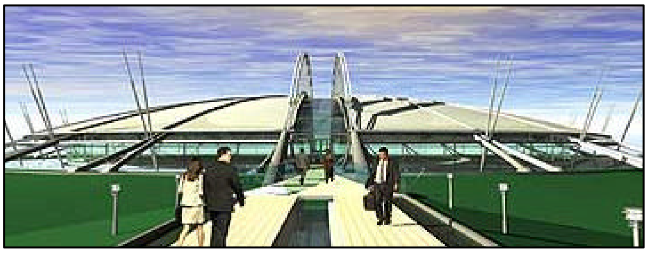
This Users Workshop is part of the process of developing the first group of Australian Synchrotron beamlines to meet the needs of Australian science and industry. It will bring together researchers using synchrotrons now and those who could use the Australian Synchrotron in the future. International experts in synchrotron design, operation and experimentation will help enhance Australian understanding of what we can expect from the Australian Synchrotron and its beamlines.

More information: http://www.synchrotron.vic.gov.au/whats_new/user_workshops.asp

NOVA—Science in the News

The Australian Academy of Science's latest NOVA story is all about synchrotrons—making the light fantastic. If you're after an excellent educational reference on synchrotrons, this is the site for you.

More info: http://www.science.org.au/nova/068/068key.htm



Conferences / Seminars

◀✧▶ **The International Straw Bale Building Conference** — **1-7 December**
Charles Sturt University, Wagga Wagga
http://www.csu.edu.au/special/strawbale/rego.htm

◀✧▶ **CSEM Seminar (followed by Xmas drinks)** — **12 December**
Tribology and MEMS, Professor Zygmunt Rymuza D.Sc.Ph.D.MEng.
Warsaw University of Technology, 3.30-4.30pm, FEIT Seminar Room, Rm 214 (FEIT Building, no. 31)
More information: Zbigniew.Stachurski@anu.edu.au

◀✧▶ **Neutron for the Earth Sciences** — **12-13 December**
Lucas Heights, ANSTO
http://www.ansto.gov.au/ansto/neut/workshop8.html

◀✧▶ **Australian Synchrotron** — **29-31 January 2003**
A workshop for potential users (see notice, above)
http://www.synchrotron.vic.gov.au/whats_new/user_workshops.asp

◀✧▶ **27th Annual Condensed Matter and Materials Meeting** — **4-7 February 2003**
Charles Sturt University, Wagga Wagg
http://www.spme.monash.edu.au/wagga/

◀✧▶ **The New Cosmology** — **3-14 February, 2003**
16th International Physics Summer School, ANU
http://www.mso.anu.edu.au/newcosmology/

◀✧▶ **IGORR 9** — **24-28 March 2003**
International Group on Research Reactors,
Sydney, http://www.frm2.tu-muenchen.de/igorr/igorr.html

Nanomaterials

Materials Grab Bag

New adventures in the nanoworld

Last month CSEM ran a stimulating one-day workshop on nanomaterials to give everyone a taste of some of the amazing research being done at ANU and around Australia.

The workshop kicked off with Professor John White (RSC, ANU) describing how an understanding of what's happening at the nanoscale might allow us to emulate nature and build some amazing substances. For example, the nacreous lining of an abalone shell is essentially calcium carbonate with some minor additions, but nature has configured it as a nanocomposite some 3000 times stronger than calcium carbonate in its pure form. The 21st century is often cited as the age of biology however John believes it's really a time in which the underpinnings of biology will be understood in terms of physics and chemistry. John outlined how his team were studying time dependent interfacial structures using a number of techniques to understand how nature built structures from the ground up.

▲▲ Tim Senden (left) chats with Neville Fletcher.

Dr Darren Martin (Nanomaterials Centre, Uni of Queensland) then shared with the audience his group's efforts on how clay nanofillers were being used to improve the engineering properties of a range of polymers. The resulting polymer-layered silicate nanocomposites have greater strength per unit weight and are cheaper than the straight polymer matrix. The challenge was to effectively exfoliate and disperse the clay particles in the host polymer, and to achieve appropriate mix ratios.

▲▲ Ian Jackson (left) shares lunch with with Darren Martin.

Next up was Dr George Simon (Materials Engineering, Monash Uni) who spoke about the testing they had carried out on a range of epoxy nanocomposites that had been prepared in a variety of fashions. Properties being tested included strength, flexibility, water uptake and fire performance.

◀◀ George Simon (left) in conversation with John White, two of the workshop presenters.

The workshop then heard from Dr Ying Chen (RSPhysSE, ANU) who discussed his work with boron nitride nanotubes produced through the ball milling of boron powder till it consisted of nanosized particles, and then heating this powder in nitrogen gas. This novel technique has the potential to overcome one of the major constraints involved with production of nanotubes: the difficulty of producing a decent yield of high quality tubes.

After a break for lunch, the workshop returned to hear Dr Tim Senden (RSPhysSE, ANU) describe his work with a force microscope to measure a range of surface forces, and so explain a variety of nanoscale behaviours that determine much of how the 'big world' works.

▲▲ Makunda Das (right) gives Zbigniew Stachurski a preview of his presentation.

Finally, workshop participants were challenged by Professor Makunda Das (RSPhysSE) as he took everyone on a quantum journey to explain electronic transport in nanomaterials.

▶▶ Ying Chen (left) with George Simon.

For more information on the workshop or any of the speakers please contact CSEM's Director, Dr Zbigniew Stachurski (Zbigniew.Stachurski@anu.edu.au).

A CSEM **SPECIAL** seminar

Tribology and MEMs

Professor Zygmunt Rymuza
Warsaw University of Technology

Professor Rymuza, author of *Tribology of Miniature Systems*, will discuss the results of nanomechanical and micro/nanotribological studies of ultrathin films (such as silicon dioxide and silicone nitride deposited by PECVD by glow discharge at atmospheric pressure, PVD superlattice hard nitride films, ion-mixed ultrathin films etc.) and MEMS materials (various silicon materials).

Date: Thursday, 12 December, 3.30-4.30pm
Venue: FEIT Seminar Room, Rm 214 (FEIT Bld, no. 31)

Followed by,

CSEM Chrissie Drinks

please join us to celebrate the end of the year

By following the fate of a tiny proton whipping about at near light speed close to the neutron star with NASA's Rossi X-ray Explorer satellite, scientists calculated this star's magnetic field to be strongest in the known universe - with a force strong enough to slow a steel locomotive from as far away as the Moon.

See: http://www.gsfc.nasa.gov/topstory/20021030strongestmag.html

CSEM

ANU Centre for Science & Engineering of Materials

Faculties
Department of Chemistry
Depart of Engineering
Department of Forestry
Department of Geology
Department of Physics

Institute of the Arts
Materials Workshops

Institute of Advanced Studies
Research School of Biological Sciences
Research School of Chemistry
Research School of Earth Sciences
John Curtin School of Medical Research
Research School of Physical Sciences & Engineering

Materials Monthly

Volume III, Issue 11

November 2002

Contacting CSEM

Director: Dr Zbigniew Stachurski / Ph: (02 6125 5681 / Email: zbigniew.stachurski@anu.edu.au

Communications: David Salt / Phone: (02) 6125 3525 / Email: david.salt@anu.edu.au

Administration: Sylvana Ransley / Ph: (02) 6125 3525 / Email: sylvana.ransley@anu.edu.au

Fax: (02) 6125 0506, Postal: Department of Engineering (Bld #32), Australian National University ACT 0200
Location: Room E112, Department of Engineering (Bld #32), cnr of North Road and University Ave, ANU

Materials Monthly comes out 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**