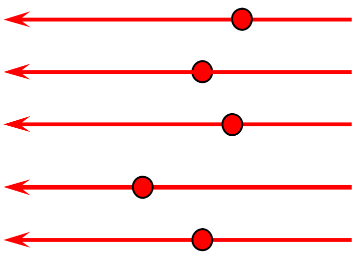
CSEM's

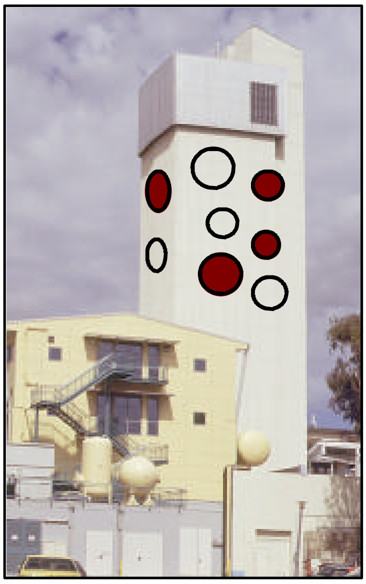
Materials Monthly

February 2004

Making materials matter

Stopping heavy ions





▲▲ Dr Tessica Weijers is playing with particles and polka dots.

Volume V, Issue 1

Materials Monthly is produced by the ANU Centre for Science & Engineering of Materials

THE AUSTRALIAN NATIONAL UNIVERSITY

Measuring and modelling tiny cannon balls with polka dot detectors

Smashing high-energy, heavy ions into different materials can produce a number of interesting results. The technique can be used to implant different elements into materials in order to modify their optical, magnetic or electronic properties. The interaction between heavy ions and materials is also one way of characterising a material's composition or structure. Heavy ions can also be used in cancer therapy to kill tumour cells with incredible precision.

However, to perform these roles it's vital to know how far the ion will penetrate into the target material. Dr Tessica Weijers at the Department of Electronic Materials Engineering (Research School of Physical Sciences and Engineering) has been working on experiments that help provide this information, and it's based on her work with a device nick-named a 'polka dot' detector.

How far a high-energy ion penetrates into a substance depends on how fast it loses its energy. The rate of energy loss is commonly referred to as the 'stopping power'. The smaller the stopping power of a material, the further a given ion will penetrate. The stopping power depends on the material being traversed, what type of ion it is, and how much energy the ion carries.

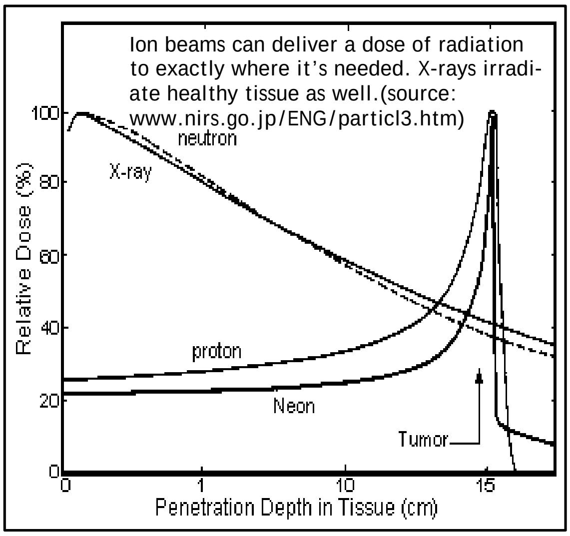
The science of stopping powers has an important Australian connection. The first measurements of stopping powers were made at the University of Adelaide exactly 100 years ago by William Bragg (see box). Since then, a knowledge of what it takes to stop a hurtling ion has found important applications in a variety of areas, notably in the treatment of cancer and materials science.

Stop at the tumour

In medicine, being exposed to a beam of heavy ions has many advantages over X-ray radiation in the treatment of cancerous tumours because they can deliver a specific dose of radiation to a precise location of the body.

When a high-energy ion enters our body, it gives up its energy as it's slowed down. The radiobiological effect in tissue is largely caused by this primary ion producing secondary ions by attracting and stripping electrons from neighbouring atoms. These secondary ions damage the DNA often leading to cell death. When it comes to treating a tumour, the aim is to kill cancerous cells while leaving healthy tissue undamaged.

The generation of these secondary ions depends on the time the primary ion is present and active in their neighborhood. When the high energy primary ion first enters a patient it's travelling very quickly, up to around half the speed of light, so it won't generate many secondary ions. However, the further the primary ion penetrates, the slower it travels and the greater the number of secondary ions it produces (per unit volume of tissue). The radiation effect rapidly increases. When the primary ion has slowed to about 10eV it no longer has enough energy to move the atoms of the target and it comes to a stop, exhausted of energy.



Ion beams can deliver a dose of radiation to exactly where it's needed. X-rays irradiate healthy tissue as well.(source: www.nirs.go.jp/ENG/particl3.htm)

The position where it stops is carefully tuned to occur at the back side of the target, which in this case is a cancerous tumour. Essentially no energy is available beyond this stopping point. This is why heavy ions are so good for radiotherapy because, if you know precisely how

(Continued on page 2)

Stopping heavy ions

(Continued from page 1)
deep they'll penetrate, you can deliver a dose of radiation to exactly where it's needed.

X-ray radiation, by contrast, delivers a diminishing amount of ionising energy all along the beam pathway. The greatest amount of radiation is received at the surface of the body, and a diminishing amount of radiation is delivered to tissue all the way down to the tumour, where it's actually needed. Healthy tissue, therefore, is often receiving high doses of radiation as well as the target tissue. This can produce unwanted side affects including the creation of new cancerous cells.

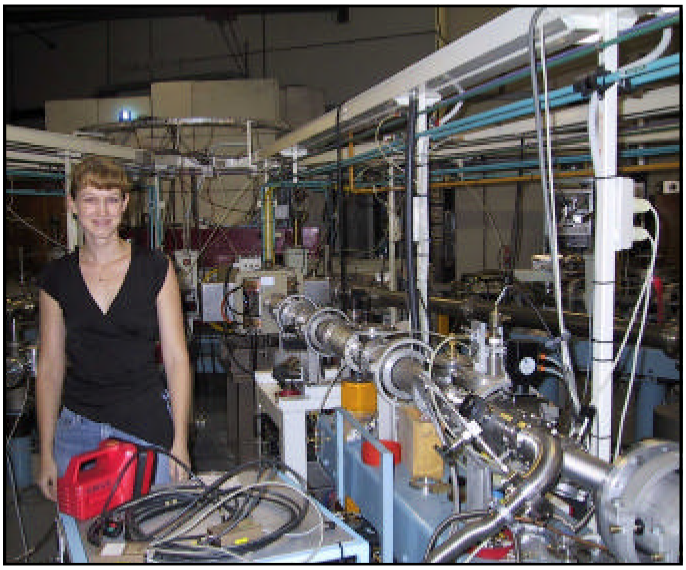
Stop right there

The key to using high energy ions in the treatment of tumours is being able to accurately predict how far the ions will penetrate. The same applies when using heavy ions to modify or characterize materials. In many materials, especially multi-layered semi-conductor materials, it's desirable to lodge ions or create defects produced by these ions in specific layers. If you're even slightly out you could well produce an entirely different effect. To lodge an ion with any precision you need to be able to predict the stopping power of the target material for that ion.

While a large number of measurements of stopping powers have been made for different heavy ions travelling at different speeds in a variety of materials, accurate prediction of the likely stopping power of a new ion-target combination is difficult.

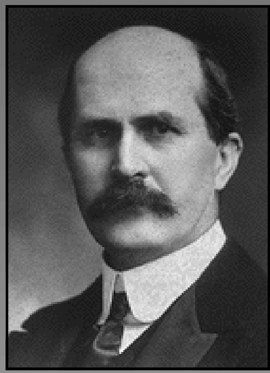
Given the value of being able to predict the stopping power of different ions, Dr Tessica Weijers from the Department of Electronic Materials Engineering together with researchers from the University of Newcastle, Lund University (Sweden) and ADFA are attempting to improve our knowledge of the stopping powers for heavy ions. A predictive model is being developed that is based on existing stopping power measurements. Also, methods for making more reliable measurements of the stopping power for new and exist-

(Continued on page 5)



▲▲ Tessica among the beamlines connected to the 14UD particle accelerator. "What distinguishes the research here is that you're expected to run the beamline yourself. It's completely hands on and you're in control."

It all started 100 years ago (in Adelaide)



The first demonstration of the stopping power of ions was carried out exactly 100 years ago and it took place in an Australian university. William Bragg, at the time Professor of Maths and Physics at the University of Adelaide, was intrigued by the nature of alpha rays, which he saw as being a completely different beast to beta and gamma rays. He predicted that the much heavier particles that made up alpha rays would only be able to penetrate so far through air before their velocity and energy were exhausted by the work done in ionising atoms in the medium through which they passed. He proposed different radioactive elements would produce alpha rays with different degrees of 'stopping power', and that by measuring the distance alpha particles would penetrate in air you could deduce the species of radioactive element that produced them.

To explore his theories, Bragg designed and built an ionisation chamber in 1904 that was capable of measuring the distance alpha particles, which were subsequently shown to be helium ions, could penetrate through air. The results, validated his model and provided a valuable key for understanding the process of radioactive decay.

His success with alpha rays put Bragg on to the international stage of physics, and encouraged him to focus his talents on even bigger fish – namely the nature of X-rays. This eventually led him and his son Lawrence to develop the field of X-ray crystallography, for which they were jointly awarded a Nobel Prize.

◀◀ Bragg's apparatus used to measure an ion's stopping power.

Words of substance

"God runs electromagnetics by wave theory on Monday, Wednesday, and Friday, and the Devil runs them by quantum theory on Tuesday, Thursday, and Saturday."

"The important thing in science is not so much to obtain new facts as to discover new ways of thinking about them."

Sir William Bragg

Many challenges in developing low-tech clay water filters

Ceramists at the ANU are confident their research will assist East Timorese villagers make ceramic water filters using local materials and methods. The work has the potential to not only improve the water supply in parts of East Timor, but could have applications in developing nations around the world.

The ceramists in question are Tony Flynn and David Goggin, and the work has been part sponsored and carried out through CSEM. In 2003 they were asked to characterise the clays and ceramics being used by the local women at Manatuto, an East Timorese village located north east of Dili (see April, 2003). The villagers had successfully produced ceramic water holders using the local clays but needed to develop a method for creating a local ceramic that might serve as a water filter to remove silt from local water supplies.

"Filtering the water involves passing it from an upper ceramic vessel into a lower vessel through 'candle filters' imported from Brazil," says Tony Flynn. "These filters are a hollow ceramic vessel filled with charcoal. They filter out suspended silt. However, at around $US5 each, they're too expensive for the East Timorese to purchase."

"Our research looked at the possibility of the East Timorese using their own ceramics as filters. Unfortunately, our results found that the local clays, by themselves, are too fine. They make good water containers but poor filters. The resulting ceramic contains little void space and quickly blocks up."

Welcome to Manatuto

"The challenge then was to see if there was some locally available material that we could add to the clay mix that might make it suitable as a water filter."

World Vision has provided grants to build a kiln, buy cones (needed to calibrate the firing of the kiln) and helped with transport to collect materials and sell their work in other areas. Basically World Vision are helping to set up and run a viable business with the villagers but will slowly hand over all responsibility to the women's group.

▲▲ David with the Manatuto villagers

World Vision has also provided funding for David Goggin to visit Manatuto and investigate what materials are locally available. During his stay he met with the local Manatuto Women's Organisation that are involved in the making and firing of the filter structures. They've set up a workshop in an old Portuguese tile making factory.

"The villagers live in fairly primitive conditions," says David. "They have some access to basic services but it's quite limited. For example, most people have running water to their house for one or two hours in the morning. During this time they fill up baths and buckets to make sure they have enough water to last the day. Any additional water must be collected from the nearest well. This is not the case everywhere. Some places have no running water and rely on daily walks to the nearest well to collect water. Manatuto also only has power from 6-12 at night. During this time people can use as much power as their fuses will allow. Paying for power is decided by how big the fuses areas."

Clay samples made with various, locally available materials

In search of local materials

David recently returned from East Timor, bringing with him samples of a variety of things available to the villagers.

"We began by looking at what happened when you added river sand, beach sand and rice husk to the clay," he says. "The idea was to add a larger particle size to the mix to open the structure up. They gave us some interesting results but still didn't provide the ceramic with sufficient porosity to serve as filters. Now we're looking at a few other locally available materials and we've made some exciting discoveries. Indeed, initial results suggest we may have the answer but we need to do more testing before we make any announcements."

The women of Manatuto fire the kiln up to about 1000°C. Unfortunately, the kiln they use is large and near impossible to maintain at an even temperature from top to bottom and front to back, even for an expert wood firer. So David and Tony are attempting to

(Continued on page 5)

Grab bag

2003 CSEM Prizes

Once again the CSEM Prizes have attracted a quality field of entrants working across a diverse range of topics. However, there can only be two winners and the judges have awarded the 2003 Prizes to Andrew Walter for best thesis in the area of applications of materials, and Christine Henry for best thesis on science of materials.

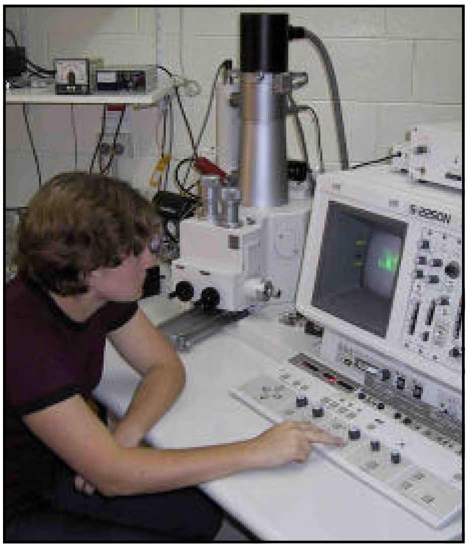
Andrew's thesis involved an impact strength analysis of field hockey shin guards. He undertook electron microscope studies of the PVC outer shell and EVA inner shell that make up shin guards, and then modelled their energy absorbing characteristics. He found that commercial shin guards are not providing sufficient protection from speeding hockey balls (which are being hit harder these days thanks to advanced composite materials being used in hockey sticks). He then created a prototype guard design using an outer skin of polypropylene with an inner skin of composite foam. The design improved energy absorption by an amazing 30%. Andrew is from the Dept of Engineering.

Christine thesis was on nanorheology: the science of rubbing surfaces on a nanoscale. She used a custom-built, modified atomic force microscope to measure both static and dynamic force components concurrently as surfaces approach, and to quantify the degree of boundary slip. Control of fluid slip behaviour through modification of static properties is of considerable relevance in lubrication, microfluidics and colloidal application. She found that the relationship of slip and shear rate is very complex and dependent on the chemical nature of the surfaces as well as the type of relative motion (constant or oscillatory).

"The quality of their research was first class," says Dr Zbigniew Stachurski, CSEM's Director. "We're delighted to reward them for their excellent work in the area of materials science and engineering, and we hope they choose to continue on in post graduate studies in the field. We're also hopeful that they'll serve as examples to other undergraduates who might currently be considering which direction of science they might pursue."

That was 2003, now it's 2004. It's never too early to alert you students to the existence of the CSEM Prizes. Winners receive a certificate and $2,000 for the best final year undergraduate thesis in the area of science and application of materials. See www.anu.edu.au/CSEM/Prizes.htm for full details.

▲▲ Much better than a kick in the shins: Prof Denis Evans, Chair of CSEM's Consultative Committee, presents Andrew with a certificate and a cheque for $2000 for winning the 2003 CSEM Prize for best thesis on the applications of materials.

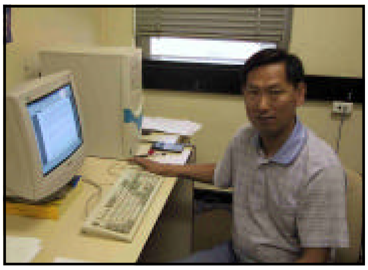


◀◀ Christine at work earlier in 2003 carrying out electron microscope studies of the AFM probe she used in her investigation.

◀◀ Denis passes on Christine's award to Dr Vince Craig, one of Christine's supervisors. Unfortunately, Christine was away at the time of the presentation practicing to be a lawyer (see did a BSc/Law degree). Vince believes awards such as this might lure her back to science.

The visitors

Professor Byung-Gak Min is currently visiting the ANU from the Department of Polymer Science and Engineering at Chungju National University in South Korea.



Prof Min is an expert in the area of curing epoxy resins using electron beams. He has brought with him a range of samples that he hopes to characterise while at ANU. He will be performing a variety of tests on the samples including electrical, chemical, mechanical and structural examinations. His other research interests includes the toughening of thermoset polymers, polymer blends of epoxy resin/polyurethane, epoxy/PPO resin systems, and thermoplastic elastomers.

Prof Min is based in the Department of Engineering. He can be contacted directly (bgmin@mail.chungju.ac.kr) or via Dr Zbigniew Stachurski (zbigniew.stachurski@anu.edu.au).
Prof Min will be at ANU till August, 2005.

Stopping heavy ions

(Continued from page 2)

ing projectile-target combinations are being developed. It's hoped the results will assist other researchers in making better-informed selections of appropriate heavy ions for work on specific materials. It's also hoped that the work will improve the reliability of existing experiments and techniques that employ heavy ions.

Polka dot detectors

So how is the stopping power of heavy ions passing through different materials measured?

The technique being employed by Tessica involves covering the front of an ion detector with a thin coat (in the order of 250 nm thick) of the material being tested. This thin coat, known as the stopping medium, is deposited on the detector as a network of 'polka dots'. The detector measures the energy of incoming ions (as an electrical pulse).

High energy ions, generated by the massive 14UD particle accelerator (situated in the Department of Nuclear Physics, RSPhysSE), are then fired at the detector. Some of the ions will pass directly into the detector. Some of the ions will pass through the polka dots of the stopping medium and then into the detector.

The energy difference between these two sets of ions (those that pass through the stopping medium and those that don't, hitting the detector directly) provides an accurate measure of the stopping power of the ion in conjunction with a specific thickness of test material. Once the apparatus is set up it's possible to carry out tests on a large number of different ion species and target materials in a relatively short space of time, allowing for the rapid accumulation of data.

"The facilities available in the Nuclear Physics Department at RSPhySE for this type of work are some of the best you'll find anywhere in the world," says Tessica. "The 14UD accelerator and associated facilities are great for generating the high energy, heavy ions we're attempting to measure. Also, the support by the department of this collaborative project has been invaluable to its success."

a polka dot detector

"What further distinguishes the research here is that you get the opportunity to run the accelerator yourself. It's completely hands on and you're in control. At many other institutions you don't have this control. By running the machine yourself you can extract so much more from the research; it's a complete learning experience. Also, you have the opportunity to actively modify what's being done and try different arrangements. It also imparts a much deeper understanding about the processes you're attempting to study."

More information: tessica.weijers@anu.edu.au

Low-tech water filters

(Continued from page 3)

mix up ceramic samples that will have a desirable final structure when fired up to 1000°C +/- 100°C.

"People use wood for cooking and to boil their water everyday," says David. "Looking around Manatuto it seemed that wood was becoming much scarcer. People have to travel further and further to get it. Ceramic water filters have the potential to greatly reduce the amount of wood previously used to boil water."

Finding the balance

Although firing to a higher temperature greatly increases mechanical strength it also decreases porosity and uses much more fuel. Alternatively, firing to a lower temperature increases porosity but decreases the structure's final mechanical strength. Part of the research seeks to identify firing parameters that will provide the best balance of porosity and strength.

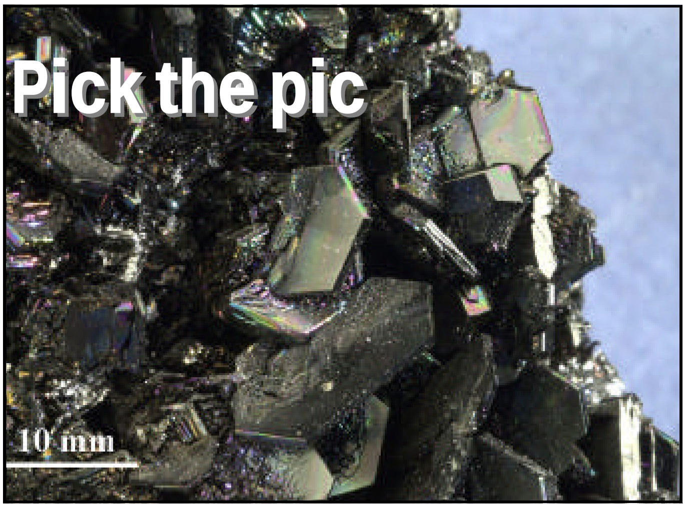
"However, it's not just coming up with the right mix for use in a western-style kiln," says Tony Flynn. "We also need to devise a relatively full proof method of firing the ceramics using their traditional techniques because the kiln is often out of action. The traditional East Timorese method is to heat clay in fires fuelled with dried cow dung. This produces a wide range of firing temperatures, and often produces inconsistent ceramics. To produce ceramic water filters we'll need to refine the way they build and use their fires to make sure they produce the appropriate range of firing temperatures."

"Even if this project is successful, the women of Manatuto then face the challenge of marketing and creating a viable business for the filters and other items made," says David. "They need to be able to pay themselves a decent wage as well as buy materials, pay for transport and wood for firing. They can do it but they'll need help in the beginning. I think World Vision is doing a good job here"

And, if successful, the research could have big spin-offs. "Terracotta clays are relatively similar the world over," says Tony Flynn. "If we can solve the problem for the people of Manatuto, I reckon we'll have something of enormous value to developing countries everywhere."

More information: Tony.Flynn@anu.edu.au

◀◀ Unpacking the fired kiln. It's important to come up with a method that works for traditional firing techniques as well.



Pictured are individual hexagonal plate-shaped grains of silicon carbide. Silicon carbide (SiC) has extreme hardness, sharpness, and good thermal chemical properties; consequently it has many applications as an abrasive or refractory material. It's produced by carbothermal synthesis in a resistor furnace, using petroleum coke and silica as raw materials. The process is known as the Acheson process (reaction is $SiO_2 + 3C = SiC + 2CO$). More than 95% of world production of silicon carbide is produced this way. The Acheson process is a highly energy intensive process being only 10 to 15% efficient. Many experimental attempts have been made to improve this process but all have been unsuccessful.

This image was taken by Dr Knowles at the University of Cambridge, and is one of many materials images available in the DoITPoMS Micrograph Library. (See http://www.msm.cam.ac.uk/doitpoms/miclib/index.php)

AMTN finds its head

The Australian Materials Technology Network is slowly taking form. It's most recent addition is the appointment of William Wachsmann as Chief Executive.

William has nearly twenty years of hands on experience in the manufacturing sector, with roles ranging from operations engineer to managing director.

He began his career with the Rolled Products Division of Comalco Aluminium, working in maintenance engineering. Following this he joined Sigma Industries (now known as Air International Transit), a specialised air-conditioning manufacturer. Here he progressed through a number of positions, commencing with the design of air-conditioning systems for high temperature industrial applications. Then he managed the Research and Development department before joining the Project Management group. He led various multi-disciplinary teams to supply specialised equipment for railway projects and played an important part in winning a number of multi-million dollar export contracts in South East Asia.

Following the completion of an MBA, William joined an energy performance contracting consulting group as Business Development Manager.

In 1998, he returned to the supply of highly engineered, specifically manufactured equipment and established the Asia Pacific subsidiary for Transtechnik GmbH, a German electronics company. In this role he grew the Australian business from start-up phase, with no orders and little brand recognition, to one with an annual sales turnover of $10 Million. In lieu of fully importing from Germany he established an assembly and testing facility in Sydney for specialised electronic equipment.

▲▲ Zbigniew Stachurski and William Wachsman met on a recent visit by the new Chief Executive to ANU.

William has Bachelor of Science and Engineering degrees from the University of Sydney and is a Chartered Professional Engineer. He also holds a Masters in Business Administration from the Australian Graduate School of Management.

The Chief Executive's office will be based in the Aust Technology Park, Eveleigh, Sydney. William can be contacted on: (02) 9209 4017 / w.wachsmann@amtn.com.au

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 2098 / Email: sylvana.ransley@anu.edu.au**

Fax: (02) 6125 0506, Postal: Department of Engineering (Bld #32), Australian National University ACT 0200
Location: Room E212, 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*, useful links and additional information about CSEM can be found at our website: www.anu.edu.au/CSEM