CSEM's

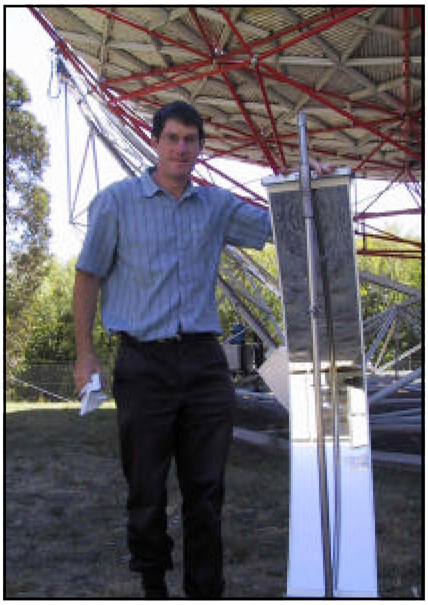
Materials Monthly

May 2004

Bringing materials into the sun

Squeezing more juice from solar mirrors

Clever solar technology stands to become even more effective with the incorporation of innovative new materials.



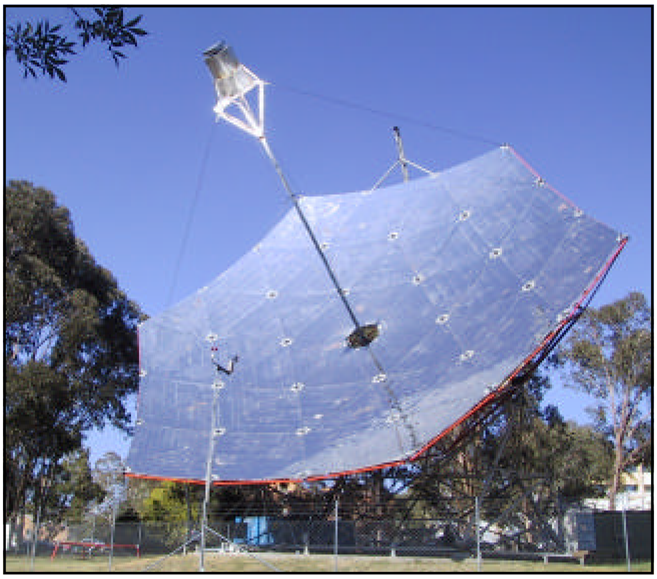
▲▲ Keith demonstrates how their system of attaching the new low-iron glass mirrors to metal creates mirrors that can bend.

Anyone who has wandered around the ANU campus would have noticed a variety of weird and wonderful mirrored arrays. The most obvious, of course, is the imposingly large Big Dish standing on the shores of Sullivan's Creek. Its massive 400 m^2 paraboloidal mirror is a Canberra icon (and is currently featured on the cover of the local phone book). Just up the hill is a smaller mirrored dish, sometimes called the Little Dish, with a more modest 20 m^2 of mirror on display. Then there are the long troughs of mirrors on top of both the Frank Fenner Building and the new Bruce Hall 'Packard Wing'.

The mirrors are all part of the solar research being carried out by engineers at the Centre for Sustainable Energy Systems (CSES). Rather than pushing the frontiers of pure science, these engineers, like good engineers everywhere, are attempting to use readily available materials and components in configurations that produce outstanding results in the field of sustainable energy. Their innovative approaches to collecting and harnessing solar energy have already demonstrated how effective solar energy can be, but recent advances on some of their basic designs suggest a lot more can be achieved, and these advances are intimately tied to the clever use of new materials.

Innovative use of clever materials

Possibly the most straightforward example of this simply involves replacing the glass in the mirrors. In recent years thin (1mm) low-iron glass has become commercially available that absorbs less sunlight than standard glass.



▲▲ By simply replacing the glass on the mirrors of the Big Dish with low-iron glass you can harvest an additional 5% of the sunlight.

"By using the thin low-iron glass in otherwise standard mirrors it's possible to increase the efficiency of the amount of solar energy reflected by around 5%," says Dr Keith Lovegrove, the researcher in charge of the Solar Thermal Group that manages the Dish concentrator systems. "The mirrors currently in use on the Big Dish reflect 86% of the solar radiation. If they could be fitted with the low-iron glass mirrors this would be lifted to 92%."

To make use of the thin low-iron glass mirrors the engineers have devised a system of fixing them to a thin sheet metal substrate to form a 'glass on metal laminate' or GOML. The system they pioneered uses an adhesive film under heat and pressure to permanently bond the 1mm back-silvered, low-iron glass on to metal sheet.

"Because the combined laminate of mirror and metal is so thin the whole unit can be flexed to form a wide range of surface configurations making them perfect for use as solar collectors," explains Keith Lovegrove. "With the glass bonded to the steel, forming the mirrors into the concave shapes needed for solar concentrators results in the glass always being under compression. As a result it can be curved a lot further than people imagine is possible."

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THE AUSTRALIAN NATIONAL UNIVERSITY

Squeezing more juice from solar mirrors

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The low-iron glass mirrors are currently only available from overseas suppliers making it a little more expensive than standard mirrors. The CHAPS solar collectors installed on the roof of the new Bruce Hall extension, represent the first high profile demonstration of the new mirror technology. The group is also seeking the resources needed to retrofit the Big Dish with new mirrors.

Well done CHAPS

CHAPS stands for Combined Heat And Power Solar, and instead of using a single large paraboloidal dish which focuses the Sun on a single point, CHAPS uses arrays of

▲▲ James sees the light (shining off the experimental CHAPS rig on top of the Frank Fenner Building.

paraboloidal mirror troughs to concentrate the sunlight into a line along which a string of high-quality solar cells are arranged. Behind the cells are pipes carrying water. The concentrated sunlight generates electricity and heats water at the same time.

"The basic idea behind CHAPS is about maximising the effectiveness of the system, and an important part of that is the cost of materials used to build it," says James Cotsell, a technician involved in the CHAPS research. "A sheet of silicon solar cells is a very clever way of converting solar radiation into electricity, and off-the-shelf solar cells can capture some 15-17% of that energy. But silicon solar cells are very expensive. Mirrors, on the other hand, are extremely cheap by comparison, even low-iron glass mirrors.

"Consider the effort required to collect the solar radiation falling on a flat square metre of ground (which, based on the global average for Earth, is around 1000 watts of energy, enough to power 10 100w light globes). You could use a square metre of silicon solar cells and you'd harvest around 15% or 150 watts. Or, you could deploy a square metre of mirror that tracks the Sun and focusses the sunlight onto a strip of solar cells 1/30th of a square metre and also harvest 15% of the energy. Both systems would harvest the same amount of energy but the mirror system could be built for a fraction of the cost of the larger panel of solar cells "

However, electricity is not the only thing being harvested by this system. The solar energy that's not converted to electricity is traditionally lost as heat. The beauty of the CHAPS system is that it also harvests this 'waste' energy by heating water running through pipes that lay behind the solar cells. It's estimated that the CHAPS collectors on top of the new Bruce Hall wing, will contribute between a third and two thirds of the annual hot water needed to heat the new building as well as provide for potable hot water (which equals an enormous energy saving when you consider heating water is one of the major uses of energy in most buildings).

On top of that, the photovoltaic array is estimated to contribute around 50% of the annual electricity consumption by residents in the new Bruce Hall building. However, before it can do that, there's one small materials issue that needs to be overcome; and it's a problem that relates to the mirrors using the low-iron glass.

Better mirrors = bigger stresses

The new low-iron glass mirrors used in the CHAPS system are a marked improvement on the mirror system that was used for a previous demonstration plant built in Perth. The original mirrors were a form of laminated glass. They were built by slumping glass on to a steel mould in the shape of the paraboloid trough. This was then coated in silver and then a second layer of glass was slumped on top.

The laminated glass mirrors were considered a low risk but expensive approach for the first system. The new GOML mirrors were developed to be cheaper and easy to mass produce. As it turns out their optical quality is also better.

"Our original laminated mirrors worked, however the process of constructing the mirror resulted in many imperfections in the trough's paraboloid surface reducing its ability to concentrate the sunlight," says James.

The new low-iron glass GOML system created mirrors that transmitted more energy but which also focussed that sunlight much more effectively, the surface of the trough having far fewer imperfections. While the original system concentrated the sunlight up around 30 times, the new system can achieve up to 100 times normal intensity.

"On the one hand, that's a fantastic outcome," says James. "However, as we've discovered, the increased efficiency of the mirrors has placed added stress on several of the components that make up our receivers.

"Our biggest problem at the moment is the material that holds our solar cells onto the receiver. It needs to be thin

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Extreme solar challenge

If the CHAPS receivers are experiencing difficulties because the mirrors are concentrating sunlight by up to 100 times, imagine the stresses being placed on materials in the receiver of a Dish concentrator where sunlight may be concentrated over 1500 times with the potential to reach temperatures well over 1000^{0}C.

Where the Big Dish is currently used to concentrate solar energy to heat water (to create steam used to generated electricity), the Little Dish concentrates sunlight that is stored as thermochemical energy. Its receiver houses a reactor which is fed with ammonia. The heat from the concentrated sunlight causes the ammonia to disassociate in an endothermic reaction into nitrogen and hydrogen which are then carried away. These elements can be stored and then be recombined later in an exothermic reaction that releases heat that can do work.

While the reactor in the receiver can cope with the intense temperatures, the front plate of the receiver surrounding the focal point has proved to be a bit problematic. With the steam receiver on the Big Dish, the problem is solved by using the feed water to cool these surfaces on the way in to the receiver. With systems like the ammonia thermochemical conversion, there is no low temperature fluid available at the receiver. Up till now, the researchers have used a sheet of steel coated in a thermally insulating ceramic applied as a paste. As the Little Dish is moved so that it can begin focussing sunlight into the receiver, great care is needed not to leave the focussed spot of sunlight on this front plate too long. It's the same as not wanting to leave a focussed spot of sunlight from a magnifying glass on your hand for too long – it causes painful damage.

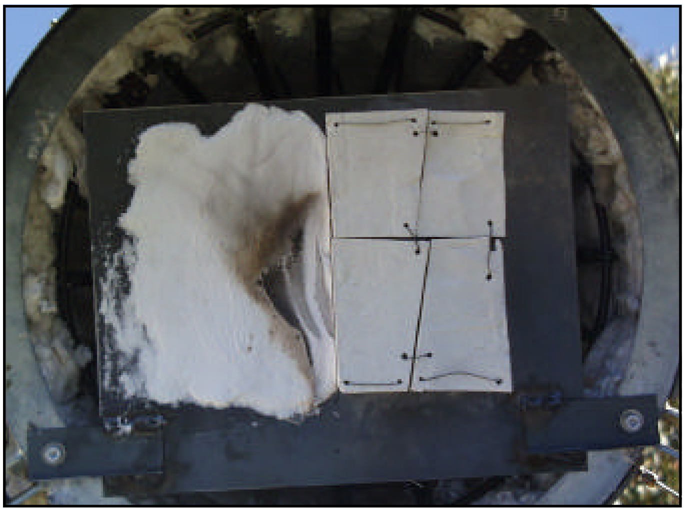
The challenge is to find a material that can shield the underside of the Little Dish's receiver and insulate the heat that builds up inside.

"Because of the intensity of the focussed spot of sunlight we've found that no matter how careful you are at tracking it onto the receiver, that with sustained use the front plate of the receiver begins to fail," says Greg Burgess, the researcher in the Solar Thermal Group leading the work on the Little Dish. "What typically happens is it begins to delaminate and warp.

"We asked CSEM if it knew of any material that we might trial as a protective shield on the front of the receiver, and we were put in contact with Tony Flynn."

Tony Flynn was formerly a ceramist working in the school of arts. He has had a long term interest between the relationship between the structure of a ceramic and its properties. He has believed for some time that if you could control the distribution, geometry and articulation of the void space within the ceramic that you create materials with a vast array of applications.

To explore what's possible, Tony has pursued this research as part of his PhD in the Department of Engineering, FEIT.



▲▲ The commercial sample on the left next to Tony's new ceramic on the right. (Note, these samples are sitting over a hole in the bottom of the receiver through which the concentrated sunlight normally passes.

His aim is to produce ceramics with a void space that are predictable in 3 dimensions over a wide range of firing temperatures.

"This is a bit of a revolutionary approach to building ceramics," says Tony. "The traditional approach is to minimise the void fraction, as this is where the structural weakness in the material is."

Part of the process is experimenting with different ingredients. Last year, Tony hit gold when he trialled a cheap industrial waste product that proved easy to work into a ceramic and allowed him to control the void space with a high degree of precision.

"This allows you to create a range of ceramics with specific properties," he says. "Some of those properties might be strength, permeability or thermal conductivity."

When the solar researchers asked if he might have a material that could be used as a solar shield, Tony was happy to see how his ceramic might perform in an extreme situation.

In March, samples of Tony's ceramic was strung up in front of the Little Dish's receiver next to an area of the plate that was also coated with a commercial ceramic paste. The test is analogous to frying two materials under a magnifying glass that concentrates the Sun a thousand times.

The ceramic coating material showed noticeable discolora-

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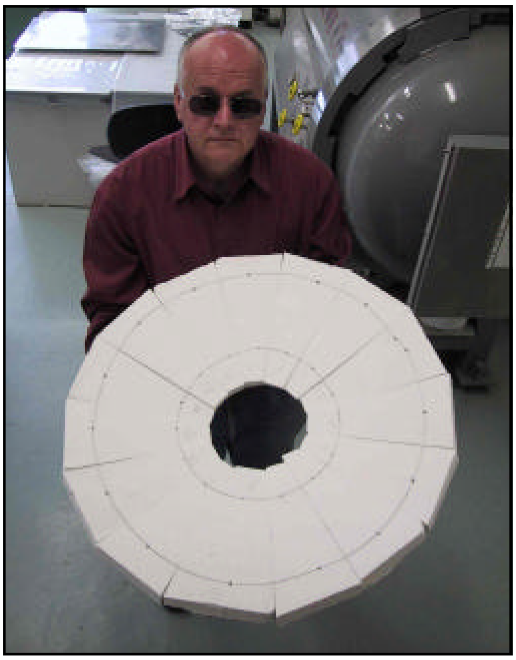
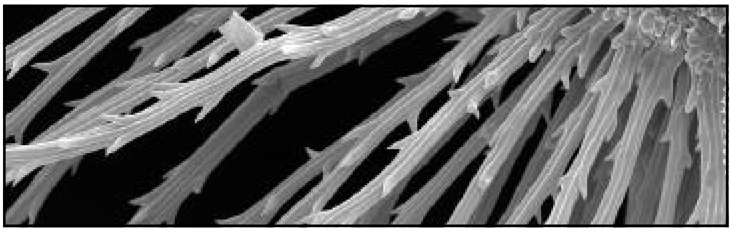


◀◀ Tony holds up a solar shield he subsequently built using his new ceramic. Early tests suggests the ceramic works a treat.

Opportunities



MIA 2004

The ANU Electron Microscope Unit presents Microscopy, Imaging and Analysis (MIA 2004). Each year the EMU, together with staff from outside the Unit, organises an introductory course running one day or more per week which covers a range of topics including image analysis, TEM and SEM, and EDXA. Research students intending to use EM in their projects are strongly advised to attend at least part of this course. The course is free for ANU staff and students (and $50 a day for outsiders).

To enrol, email stowe@rsbs.anu.edu.au and provide your name, department, your course or position, and the sessions you wish to attend.

2004 Outline

Series I (Sessions are held in RSBS and start at 9 am sharp. The usual format is a morning of lectures and discussion, and an afternoon of practical work in the EM Unit.)

1. Light Microscopy - 2D and 3D Imaging and Deconvolution Methods.
Wednesday 26 - Thursday 27 May.
This is an overview session, working from the basics of light microscopy to more specialised techniques including DIC, epi-fluorescence, confocal, computational and "Apotome" deconvolution methods, and an introduction to some 3D reconstruction software packages.

2. Understanding and Manipulating Images, from acquisition to publication.
Tuesday 1st June (Pre-requisite for most later sessions)
Principles of digital image acquisition with emphasis on light and electron microscopes, processing the image to reduce noise or emphasis features, introduction to some commonly available measurement and image processing programs, things to consider when printing. Depending on participant numbers, additional practical sessions may be scheduled later in the week.

3. Introduction to SEM
Tuesday 8 June (Pre-req: session 2)
An introduction to EM columns and to the principles of Scanning Electron Microscopy. Note that many of the basics common to both SEMs and TEMs will be covered only once in sessions 2 and 3.

4. Introduction to TEM
Wednesday 9th June (Pre-req: session 2&3)
Continuation of introduction EM columns, and to the principles of Transmission Electron Microscope operation.

5. X-ray Analysis of Elements
Tuesday June 19th (Pre req: sessions 3 & 4)
An introduction to the analysis of elemental composition by energy dispersive (EDXA) and wave-length dispersive (WDS) x-ray analysis.

Series II
Topics covered vary from year to year - please indicate if you would like to attend any of these courses in 2004, or feel free to suggest others.

6. TEM II - basic theory and practice for Diffraction, Darkfield and Convergent Beam applications. (Recommended that you have done sessions 2,3 & 4)

7. Cryotechniques in Electron Microscopy
(Pre-req: session 3&4)
Ice crystal formation and the advantages and disadvantages of different methods of freezing samples. The type of applications emphasised in the practical sessions may depend on the background of the participants

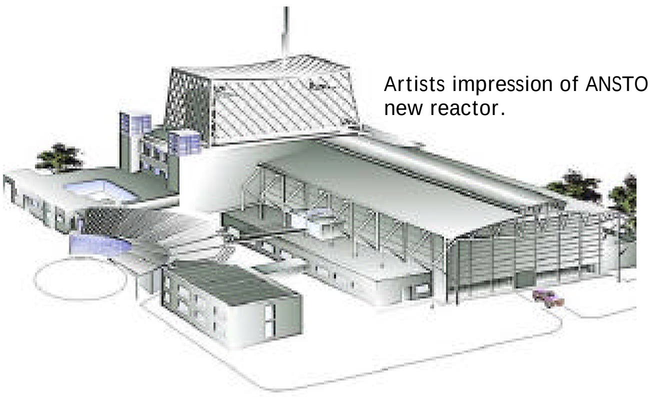
8. EM-related Focused Ion Beam techniques.
(Pre-reqs: sessions 2,3&4 or equivalent).

More info: http://www.anu.edu.au/EMU/training.htm

Keeping up with ANSTO

Each month the Australian Nuclear Science and Technology Organisation's (ANSTO) Business Development (ABD) Unit produces an online newsletter ezine titled BusinessANSTO. The current issue has an update on the replacement research reactor, an article on radiopharmaceuticals for molecular medicine and introduces Dr Ian Fraser, ANSTO's new Executive Director.

To subscribe (it's free) or check it out, go to:
www.ansto.gov.au/abd/news/ezine/ezine.html



Artists impression of ANSTO's new reactor.

Fellowship in Food Engineering

This is an excellent opportunity to study in one or more of the UK's renowned centres of food engineering teaching and research from between three to six months with a grant up to GBP6000. Applications are invited from graduates under the age of 35 years, who are normally resident outside the UK and who are particularly involved in food engineering in their home countries.

The Seligman APV Trust is admininstered by the Society of Chemical Industry. SCI is an interdisciplinary and international organisation covering a wide spectrum from agriculture, construction and environmental protection to pharmaceuticals and food.

To apply for the Fellowship state clearly (maximum 200 words) what your achievements have been to date and what you would hope to gain from the Fellowship for yourself, your organisation and your country.

Entries close 31 July 2004

Applications and mor info: www.soci.org (and go to the 'Education' page).

Squeezing more juice from solar mirrors

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and a good heat conductor so that the heat is efficiently transferred into the water channels in the receivers. However, it also needs to be an electrical insulator because the photovoltaic cells need to be electrically isolated.

"With the old mirror system we used a double sided tape that performed well. However, the new improved mirrors are producing heats that literally char this tape, so the search is on for a replacement adhesive."

The hype on heat

"A quick surf of the Web reveals a mind bogglingly large array of tapes, adhesives and pastes designed to stick components together, keeping them electrically isolated while effectively transporting the heat away," says James. "This makes sense when you consider that 'thermal management solutions' are a hot topic of R&D these days as electronic components become smaller and more powerful and the need to dissipate heat more critical.

"Given this, I thought it would be easy to select one for use in our CHAPS receivers. However, it's actually proved a difficult and frustrating job as each product comes with limitations. Some require mechanical fastening, others provide too rigid a bond (and our receivers are constantly expanding and contracting), still others creep or ooze during curing and use, and some simply aren't up to the extreme conditions experienced by componentry on the receiver."

The most critical factor of concern in these materials are their thermal transfer properties and whether they really perform as indicated by their specifications. To test this, James built his own low-budget calorimeter to test rates of heat transfer in a variety of materials (see box)

"We think we've identified an adhesive tape that's up to the task," says James. "The next task is to see how they perform in real life. We're putting a batch of test receivers into our experimental CHAPS rig on top of the Frank Fenner Building. If these tests go well we'll then put together a series of receivers for the mirrors on top of Bruce Hall."

The Bruce Hall CHAPS system is therefore getting very close to coming on line. For the engineers at the CSES that's great news as it will serve as an excellent demonstration of the power and the efficiency of the CHAPS system, and hopefully lead to its commercialisation.

The Bruce Hall CHAPS project is supported by Rheem/Solahart Australia and the Australian Greenhouse Office.

More info on the Dish systems and mirrors: Keith.Lovegrove@anu.edu.au
More info on CHAPS: James.Cotsell@anu.edu.au

Calorimetry on a shoe string

To measure heat transfer in a variety of materials, James used a pair of aluminium blocks. The material being tested is sandwiched between the two blocks. Heat is added to one block via an electrical resistor, and then measured in the other block using a thermocouple. The whole apparatus is contained in a heavily insulated foam box. By measuring the rate of change of temperature in the two blocks it's possible to calculate the thermal conductivity of the test materials to an accuracy within an order of 0.7 ^{0}C, more than enough for purposes of this study.

While the low-budget apparatus wasn't super precise, it was good enough to tell James that several of the test materials didn't perform as indicated by their specifications.

"As companies can't quote spurious results, I can only believe that the values they've cited must have been achieved under optimal conditions," says James. "These would include bonding methods designed to achieve maximum wetting of the bonding surfaces and the perfect pressure for bonding."

"We weren't interested in theoretical specs under optimal circumstances. We simply needed to know how it would function under our working conditions."

▲▲ James and his low-budget heat transfer measuring rig.

(Continued from page 3)

Extreme solar challenge

tion after only 30 seconds, and was found to have substantially delaminated from the plate on inspection at the conclusion of the experiment. Tony's ceramic, by contrast, displayed no observable change, even after 20 minutes of constant exposure to concentrated solar radiation. A remarkable outcome.

"I'd say that Tony's ceramic is quite special," says Greg. "Until now we've been unable to find anything that would do the job we wanted. We've tried a number of commercially available preparations and materials – and they've all failed, even though their specs indicated they should have been okay.

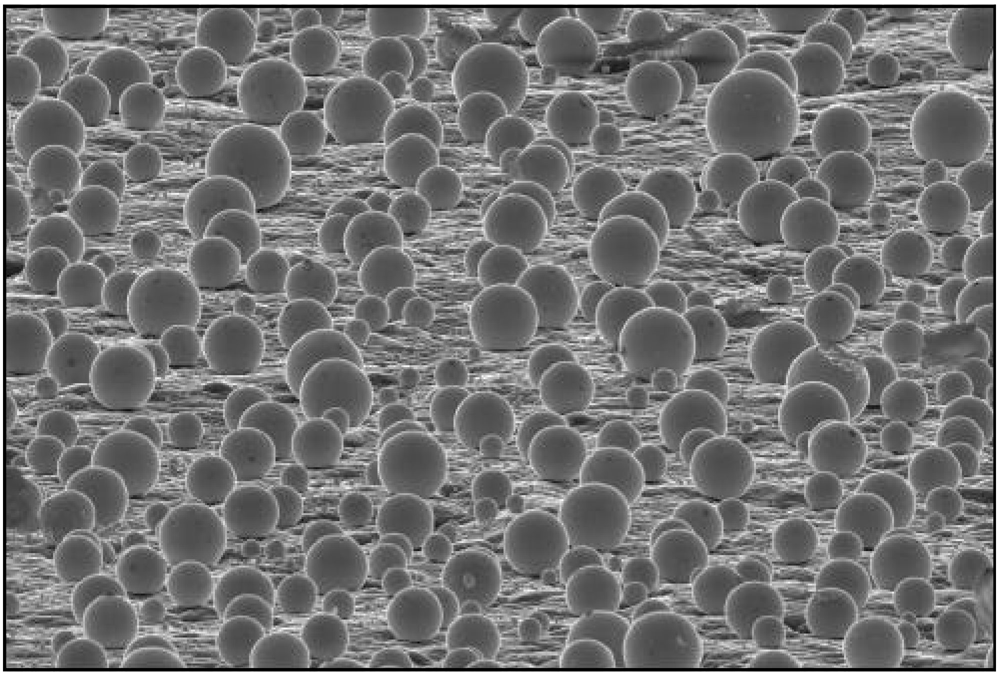
"Following this test we asked Tony to build for us a working shield for the receiver of the Little Dish," says Greg. "Initial indications are that it'll work well which will make the operation of the Little Dish a lot more effective. It's not just about protecting the front of the receiver, it's also about keeping the heat inside the receive to boost the reaction. Tony's ceramic looks like it can do both.

"This is great for us, because finding materials that can protect and insulate for long periods in extreme conditions is an important part of solar research. This could be the beginning of a very fruitful association."

Tony is continuing his research on this new class of ceramics, and we expect to bring you further developments in future issues of Materials Monthly.

More info on the Dish systems: Greg.Burgess@anu.edu.au

More info on the ceramic shields: Tony.Flynn@anu.edu.au



Pick the pic

Gold balls

This is what happens when you hold a blow torch for a couple of seconds to a thin layer of gold on a carbon substrate - thousands of tiny gold balls. The bigger ones are up to 20 microns in diameter with the smaller ones going down to sub-micron sizes. The range of tiny gold balls make for an excellent target for scanning electron microscopes to test their focus and contrast settings on.

This intriguing image was captured by Dr Roger Heady at the ANU Electron Microscope Unit.

If you have an excellent materials-related image we'd love to run it. Send it to David.Salt@anu.edu.au

AUSTRALIAN SYNCHROTRON RESEARCH PROGRAM

Synchrotron Research Fellowships

Applications are invited for the 2004 round of Australian Synchrotron Research Program (ASRP) Post Doctoral Fellowships. **The closing date for applications is 7 June 2004.** Up to six Fellowships will be awarded: the fellowships can be held at any eligible ASRP member institution.

The aim of the ASRP Research Fellowships is to attract outstanding young Australian scientists to areas of research that involve either the use of established synchrotron radiation techniques to solve important problems or the development of synchrotron radiation techniques or instrumentation.

The Australian Synchrotron Research Program offers these Fellowships in line with its mission to increase the number of synchrotron-literate scientists who will be capable of contributing to the use, operation and management of the Australian Synchrotron Facility when it comes on stream in 2007.

The ASRP member institutions who are eligible to host ASRP Fellows appointed in the 2004 round are:

- ⇨ The Australian National University
- ⇨ ANSTO
- ⇨ CSIRO
- ⇨ The University of Newcastle
- ⇨ The University of Queensland
- ⇨ The University of Western Australia

More info:
http://www.ansto.gov.au/natfac/asrp_fellows.html

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