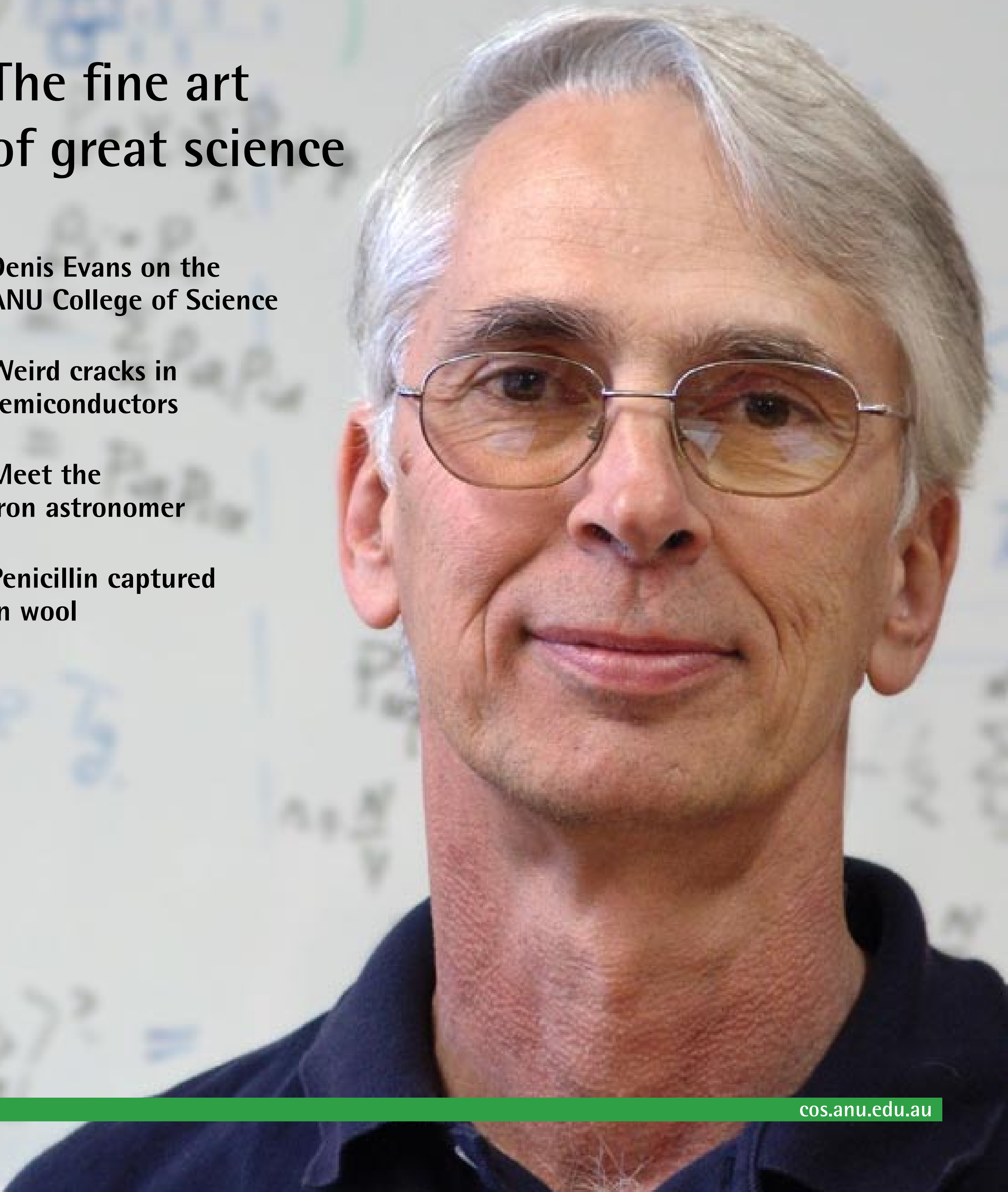
Newsletter of the ANU COLLEGE OF SCIENCE

Volume III No. I

SCIENCE WISE

THE AUSTRALIAN NATIONAL UNIVERSITY

The fine art of great science



Denis Evans on the ANU College of Science

Weird cracks in semiconductors

Meet the iron astronomer

Penicillin captured in wool

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Cover image:

Professor Denis Evans is the Convenor

of the new ANU College of Science

(see story on page 3).

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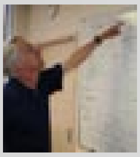

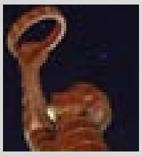

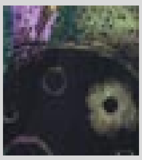

SCIENCE WISE NEWS

PLASMA THRUSTER TESTED

Technology invented by ANU physicists could see expeditions to Mars become a reality, with the European Space Agency (ESA) announcing it will begin full-scale trials next year.

The Helicon Double Layer Thruster (HDLT) technology to be used by the ESA was developed by Dr Christine Charles and Professor Rod Boswell from the Research School of Physical Sciences and Engineering at ANU.

The technology was recently verified at the Ecole Polytechnique in Paris, one of the great research centres in France, under a contract from Dr Roger Walker of the Advanced Concept Team of ESA. The French group was lead by Dr Pascal Chabert who has been collaborating with the ANU group for nearly a decade and has spent many months working with Dr Charles and Professor Boswell.

The HDLT uses solar electricity from the sun to create a magnetic field through which hydrogen is passed to make a beam of plasma, powering ships through space.

While the plasma thruster has a fraction of the power of the rockets that launch the space shuttle, it uses far less fuel and gets more thrust as a ratio of the fuel it burns, making it ideal for interplanetary missions.

More info: prl.anu.edu.au/SP3/research/HDLT

NEW PLANET DISCOVERED

A ground-breaking discovery in the search for planets that may support life in our galaxy has been made by an international team of astronomers, with critical data provided by Australian team members.

The newly-discovered planet is exciting because it has a number of attributes that are similar to those that astronomers believe are needed to exist to support life, and indicates that these types of planets might be common beyond our Solar System.

Credit: NASA, ESA, ST SCiI.

The small, cool planet — called in typical astronomical terms 'OGLE-2005-BLG-390Lb' — orbits a star in the inner Milky Way, weighs in at around five times the mass of Earth and is one of the least massive discovered so far. It orbits its parent star at a distance three times the distance of Earth from the Sun, and one orbit takes 11 Earth years.

The planet was identified by astronomers from 32 institutions in 12 countries working on a collaborative project, and included the Director of the Research School of Astronomy and Astrophysics (RSAA) at ANU, Professor Penny Sackett. The results of their research are published in the latest edition of Nature.

"This tremendously exciting discovery provides tantalising information about the potential of our galaxy to house another Earth-like planet, where conditions are conducive to some form of life," Professor Sackett said. "We're getting closer to discovering an Earth-twin."

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SCHOLAR SOLVES PUZZLE

Finding a solution to a mathematical puzzle unsolved for over 15 years has recently won an ANU mathematical physicist two prestigious awards

Professor Rodney Baxter, from the Mathematical Sciences Institute at ANU, received both the 2006 Onsager Prize of the American Physical Society (APS) and the separate Onsager Lectureship and Medal for 2006 from the Norwegian University of Science and Technology.

Both prizes are named for widely respected theoretical physicist and Nobel Laureate Lars Onsager, who exactly calculated the order parameter of the Ising model in 1949. This was the first such calculation for a statistical mechanical model of magnetism. He received the 1968 Nobel Prize in Chemistry for his earlier work on irreversible thermodynamics.

"These awards are particularly pleasing for me as it is recognition of work on the order parameters of the chiral Potts model, which is research in the Lars Onsager tradition," Professor Baxter said.

In his research, Professor Baxter showed by careful mathematical analysis that numerical predictions about the order parameters of the chiral Potts model were exactly right, something which had been elusive for mathematicians in the 15 years before his proof.

Simply, the complicated chiral Potts model is a prototype of theoretical descriptions of the interaction and behaviour of materials at the molecular level. It includes the Ising model as a special case.

The "exact solution" of the chiral Potts model achieved by Professor Baxter has important implications in the physical sciences. It greatly increases confidence in theoretical models, particularly in materials science, where physicists around the world, and at ANU, are building next generation electronic devices using two-dimensional layers in 'chips'. These specialised 'chips' may eventually be used in computing, audiovisual technologies and advanced telecommunications.

Working together across the College of Science

by David Salt

As far as Professor Denis Evans is concerned, the new college structure being established across ANU is all about researchers, lecturers, support staff and students working more effectively together. As Convener of the new ANU College of Science, the largest of the seven new colleges, Professor Evans believes there will be many challenges in making this happen but the rewards will be many.

"We have two main aims in establishing the ANU College of Science," says Professor Evans. "One is to better align our teaching programs with our research strengths, and the other is to improve our strategic planning across schools and faculties. As Convener my responsibility will be to focus on strategic planning and related activities while it will be Professor Tim Brown's role as Dean to look after its educational programs.

"Taken as a whole, the ANU College of Science represents one of Australia's real powerhouses of research and teaching. Our component institutions include five research schools from the Institute of Advanced Studies as well as a University Centre, an Institute and the Faculty of Science with its diverse range of departments and schools.

"Each of these institutions have their own histories, strengths and cultures; and each are involved in ground-breaking science with track records most other places just dream about," says Professor Evans, who is also the Dean of the Research School of Chemistry (RSC). "However, while individual schools, centres and departments might be powering along it's not uncommon that one institution is unaware of what's happening in another school or department on the other side of campus. That applies to research, to teaching and even to basic day-to-day administrative procedures.

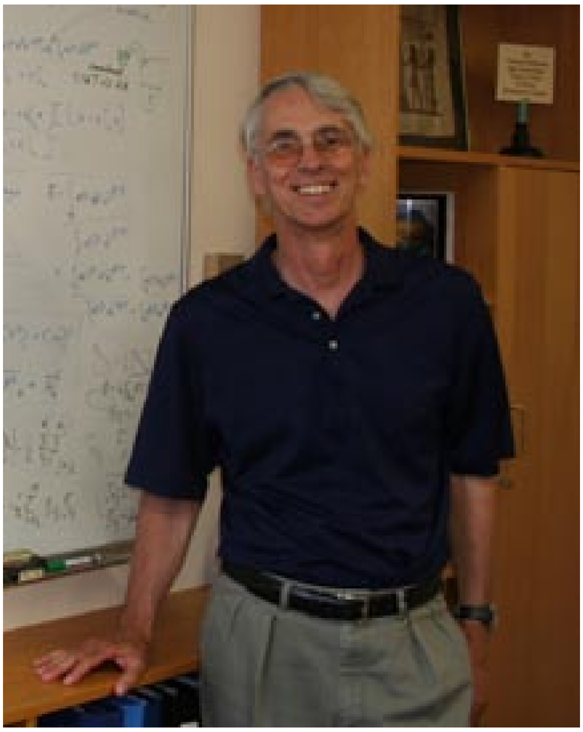
"Taken as a whole, the ANU College of Science represents one of Australia's real powerhouses of research & teaching. "

"If you're engaged in world-leading research it only makes sense that you're capitalising on that strength in your teaching programs but that sometimes isn't happening. For example, here at the Research School of Chemistry we have extensive research capacity in the area of biological chemistry – the chemistry of photosynthesis and DNA replication and so forth. Indeed, around a quarter of the School is in someway involved in one form of biological chemistry or another, and some of our research in these areas is truly leading the world. However, the Department of Chemistry in the Faculty of Science offers little in the way of undergraduate training in these disciplines meaning we're really not making the best use of the university's research strengths in these areas.

"I'm happy to report that the new college structure is already improving this situation. It was through college-based discussions between the school and department that this gap was identified, and is now being addressed with the joint appointment of Professor David Ollis between RSC and the Department of Chemistry. David's expertise is in protein function, and by joining the Department of Chemistry he'll be building bridges between RSC and the department in an important area of biological chemistry.

"The hope is that we'll see many more bridges being built between the research schools and faculty departments over time.

"Part of the college management process is having representatives of its various member groups regularly meet and share information for decision making. This will apply to research and teaching programs but it will also apply to administration, human resource management and marketing," says Professor Evans.



"... many of the biggest breakthroughs and the most important science actually occur when you bring together elements from different areas," says Professor Evans.

"A good example of where this is already paying dividends has been in sharing information on procedures for travel. Each school and Faculty department has their own system, each with strengths and weaknesses. When representatives from the various groups met and looked at each other's systems it became clear that the computer-based system established at the Research School of Earth Sciences provided significant savings in time and effort, and this system is now being implemented in several other schools and departments.

"By learning about each other and sharing information we can capitalise on our strengths, identify and fill gaps and seize emerging opportunities. When we hire new staff or implement new research it will be done in an integrated fashion, knowing what other schools and faculty departments are doing. When the government announces new research priorities and funding schemes we'll be in a position to present better coordinated bids.

"It's easy to be cynical about new structures like the colleges. People are tired of continual change and often question the worth of more change, but I believe the College structure will make a genuine difference in the various institutions, schools and departments with each group knowing more about each other and making better decisions as a consequence."

And when it comes to the value of working across disciplines, Professor Evans speaks from experience. He started out in science studying astrophysics at the University of Sydney. During a vacation scholarship at CSIRO he was introduced to statistical mechanics and earned a PhD in this field at the Research School of Physical Sciences (ANU). However, he then branched out into chemistry at Oxford and then chemical engineering at Cornell. When he eventually returned to ANU it was as a 50/50 appointment between the Mathematical Sciences Institute and the Research School of Physical Sciences & Engineering.

"My science has travelled across a number of disciplines," says Professor Evans. "It's been my experience that many of the biggest breakthroughs and the most important science actually occur when you bring together elements from different areas.

"My biggest breakthrough came about by taking dynamical systems theory and applying it to statistical mechanics. This has rewritten our basic understanding on aspects of the structure and dynamics of fluids and yet back in the early nineties no-one saw the value in mixing two seemingly disparate scientific disciplines.

"Science and research are always on the move, often in directions you can't predict," says Professor Evans. "It's like riding a wave and it's surprising where this wave might travel. Any institutional structure that offers you a greater opportunity to take your science in different directions and across disciplines is only going to improve that science. I'm confident that this will be one of many advantages offered by the new college structure.

"The next few years promises to be a very interesting time for science and research at ANU."

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A winning five for RSC

When ScienceWise visited the ANU Archives for this issue's historical story (see page 5) we couldn't help but notice the above photo from the Research School of Chemistry. It fits nicely with Professor Evans' comments on research excellence in science at the ANU. This photo shows five members of the Research School of Chemistry in 1983 celebrating recent awards and honours.

From left to right they are a young Dr Denis Evans (who had just been awarded the Rennie Memorial Medal by the Royal Australian Chemical Institute, RACI), Mr Rod Rickards (H. G. Smith Medallist of the RACI), Professor Alan Sargeson (elected as a Fellow of the Royal Society), Professor Arthur Birch (recipient of the Royal Society of Chemistry Natural Products Award) and Professor Lew Mander (elected as a Fellow of the Australian Academy of Science).

Photo courtesy of the ANU Archives Program. For more info on the ANU Archives Program: www.archives.anu.edu.au

Blowing through the years

"Scientific glassblowing takes years to learn but decades to master," says Chris Tomkins, the man in charge of the Glass Workshop in the Research School of Chemistry (RSC). And he should know. He's been honing his skills for several decades as the picture above attests. It shows a young Chris Tomkins back in 1975 demonstrating to visitors some of the skills involved in producing scientific glassware during an ANU open day.

He's still creating weird and wonderful pieces but these days his trade is not so well represented. Mr Tomkins is one of the few glassblowers around who's still practicing this highly skilled profession. Unfortunately, like so many of the specialised technical trades that once flourished within the research schools on campus, scientific glassblowing is no longer a widely practiced craft.

"There used to be seven glassblowers on campus," says Chris. "This included workshops at RSC, the John Curtin School, the Research School of Earth Sciences and the Resarch School of Physcial Sciences and Engineering. RSC had three glassblowers to service its needs."

Now it's just Chris and his off-sider, Paul Siu. Their glassblowing workshop not only produces specialised scientific glassware for RSC but for all of ANU. On request, it's also available to do work for other labs around Canberra and the region.

Chris Tomkins in the Glass Workshop at RSC today (above) and back in 1975 (top).

Almost all scientific glassware begins life as a tube or rod of glass. This gets blown, stretched, cut and joined into a bewildering range of shapes and forms. Some of the creations having the complexity and challenge of building an intricate ship inside a bottle.

Glass is an amazing material to work with. Chris says anything you can do with metal or wood, you can do with glass.

"However," he cautions, "you always need to take care with glass because it jumps up and bites you from time to time."

Which may be why attaining a qualification in scientific glass blowing can take over five years. In 2001 an assessor came out to Australia from New Zealand to assess Paul and awarded him the British Society of Scientific Glassblowers Certificate of Competence.

Thankfully, therefore, the long and distinguished tradition of scientific glassblowing will still be available at ANU – at least for the foreseeable future.

Photo courtesy of the ANU Archives Program. For more info on the ANU Archives Program: www.archives.anu.edu.au

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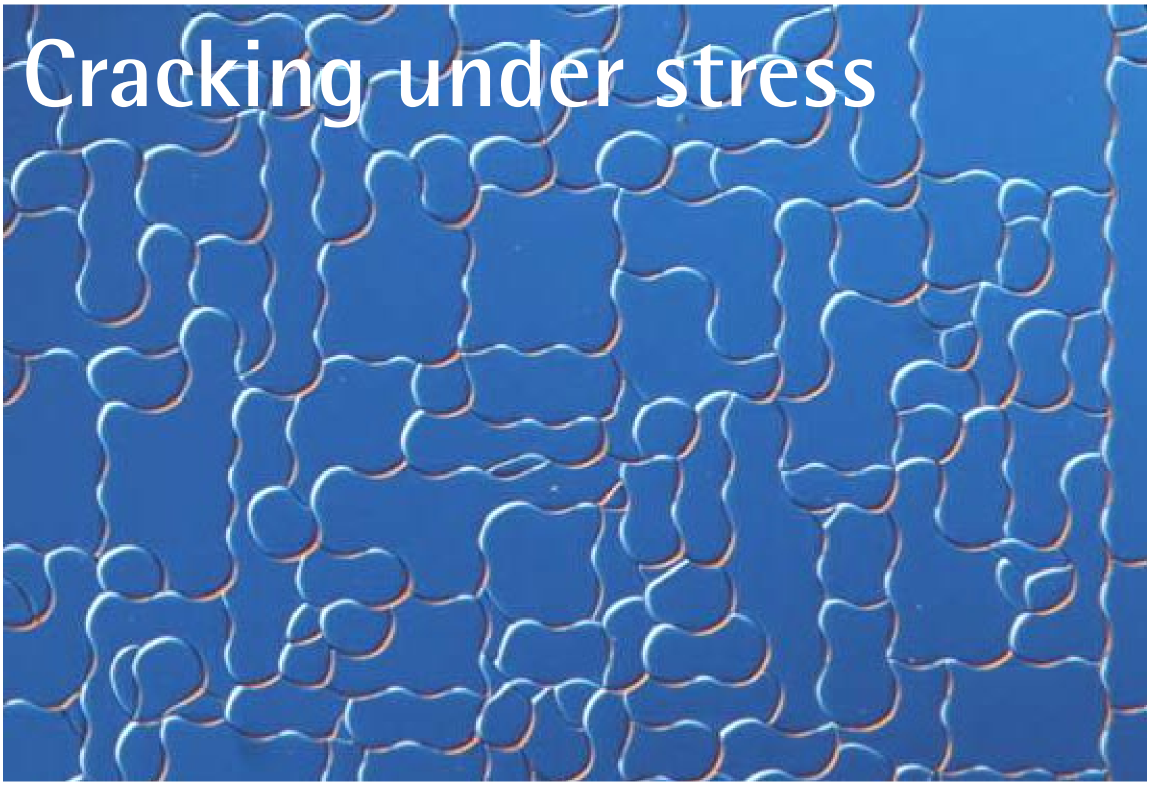
Cracking under stress

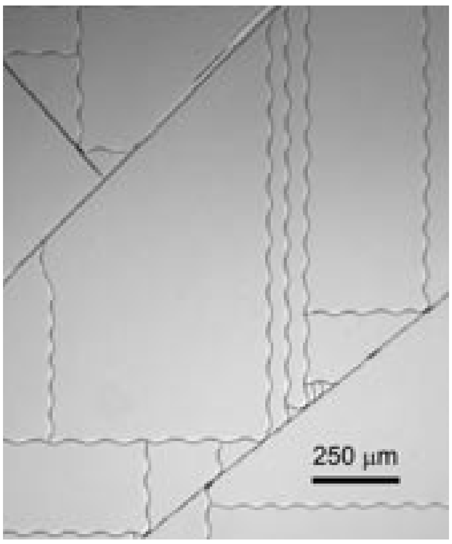


The researchers at Electronic Materials Engineering have observed many bizarre variants of the cracking behaviour. Pictured to the left is a form they have dubbed 'chain-mail' created from a network of interlinked wave cracks.

The researchers call the cracking pattern shown below the 'snake skin' for obvious reasons. It's formed by two parallel straight cracks with repeated curved cracks in between. This form of cracking occured relatively slowly, over several seconds. It could be observed happening by eye. The wavy cracks, in contrast, grow very quickly, too fast to observe.

by David Salt

As scientists build increasingly complex structures from deposited thin films they're discovering a host of new problems relating to the physical nature of these layered systems. Stresses building up inside the layers can lead to cracking and distortion of films, and to failure of devices based on these films. Professor Rob Elliman, Dr Tessica Dall, Mr Marc Spooner and Mr Taehyun Kim from the Department of Electronic Materials Engineering (in the Research School of Physical Sciences and Engineering) have recently witnessed a particularly amazing form of cracking behaviour in amorphous silicon-rich oxide films deposited on silicon wafers.

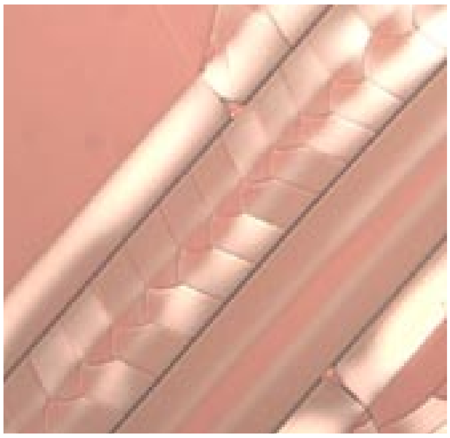


In the image above, cracks in the thin silicon films are clearly following an alignment corresponding to specific crystallographic planes in the underlying silicon crystal that makes up the substrate. The wavy cracks have never been observed before and the exact mechanism by which they are created is still being investigated.

"We've observed two novel modes of crack propagation, one that produces straight cracks and a second that produces near-perfect sinusoidal, or wave-like, cracks aligned along different directions," says Professor Rob Elliman, who heads the Department. "The sinusoidal cracks have a wavelength of around a hundred micrometres and can propagate over centimetre distances with near constant form. This long-range periodicity suggests a simple interplay between two competing processes and we are trying to understand these in detail."

The silicon-rich oxide layers are being deposited on silicon substrates by plasma-enhanced chemical vapour deposition. Individual layers are between 100-1500 nm thick. After the film has been deposited it is then heated to 1100ºC to precipitate out silicon nanocrystals. It's during this heating that the cracking occurs.

"It appears that straight cracks begin to form first followed by the wavy or oscillating cracks," says Elliman. "Both sets of cracks, straight and wavy, lie parallel to particular crystallographic directions in the underlying silicon substrate. Interestingly,



the wavy cracks do not appear to have been observed before in such thin films. However, similar cracks have been observed in rubber stretched one way more than another."

To understand what's happening Professor Elliman's team has been studying several aspects of the process, specifically the effect of heating on the film stress and the amount of hydrogen the film contains.

"Understanding how stress develops in thin films and why and how cracks form is fundamental to the successful application of thin film technologies," says Professor Elliman. "Our results show that hydrogen release can be used to tailor the stress in thin films to produce stress-free films or films with a particular stress. This is particularly important to the builders of micro-electro-mechanical systems, or MEMs, where film distortion or failures caused by internal stresses can quickly destroy a device."

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The iron astronomer

by David Salt

There's a solitary figure standing outside Questacon – The National Science and Technology Centre. It's perched up on a large, rusting spoked wheel marked out like a compass, and it holds over its head a steel ring through which it studies the stars above. Frozen in time, the sculpture celebrates the research of the Mt Stromlo Observatory and commemorates the day a wildfire passed through the observatory in 2003 destroying everything in its path.

The declination wheel of the historic Yale-Columbia telescope (pictured above) was used as a base for the iron Astronomer.

Tim Wetherell installing the astronomer outside of Questacon

"As well as the obvious setbacks to scientific programs, several large and historically significant telescopes were destroyed in that fire," said Dr Tim Wetherell. "None of these telescopes can be restored, but it seems fitting that their remains continue to serve some role."

And so it was that Dr Wetherell, a prominent Canberra sculptor who also works as a science communicator at the ANU Research School of Physical Sciences and Engineering, was asked if he could fashion a memorial work of art from the remnants of the once mighty telescopes. After picking through the wreckage he finally decided that the declination wheel of the historic Yale-Columbia telescope would serve as an appropriate base to a figure made of iron gazing up at the heavens.

"I wanted to create a sculpture that would be accessible, that would link the telescope to the community and show the scientific vision and aspiration of astronomers," he said.

"The pose and gesture of the iron figure speaks of astronomy and examining the heavens, whilst the riveted plates give strong ties to the appearance and 'flavour' of the original 1920's telescope."

The Yale Columbia was a 26 inch refractor built at Yale University in 1924. It was one of the largest refractor telescopes of its kind ever built and was relocated to Mt Stromlo in 1952 where it played a valuable role in many research projects. As recently as 1998 it was used in a long term project measuring stellar parallaxes to calculate distances and proper motions of nearby stars.

The telescope is no more but its spirit lives on in 'the astronomer' gazing skyward outside Questacon. The sculpture, which stands 6m tall and weighs close to a ton, was unveiled at the end of last year.

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Tim Wetherell examines the burnt stem with the declination wheel

Stella fractus

The iron Astronomer wasn't the only sculpture Dr Wetherell created from the ashes of the Mt Stromlo fire. His first work consisted of a huge spiked sphere (1.3m in diameter pictured below) using shattered glass from the Great Melbourne Telescope. This glass has been thermally stress fractured into thousands of fractures ranging from a few millimetres to several centimetres in size.

The collected fragments had to be cleaned on site to remove as much debris as possible and the broken down into smaller pieces along the existing fracture lines by tapping with a hammer. The resulting pieces of glass looked rather like diamonds or crushed ice. Unfortunately, these beautiful fragments also had razor sharp edges which had to be removed by tumbling in an air tight container before a final washing. The treated glass fragments were then used to cover the surface of a giant Perspex sun. The natural granularity of this glass surface resembles that of the real sun especially when internally lit by an electronic fire effect designed by the Electronics Unit at the Research School of Physical Sciences and Engineering.

The sculpture, which became known as stella fractus, was used as a major draw card at several local science events including the Australian Science Festival and National Science Week.

Florey captured in wool

by David Salt

It took nine months of solid weaving to achieve but Valerie Kirk has now completed the three Nobel tapestries commissioned to celebrate the 50th birthday of University House. Each tapestry took around three months to produce and each reflected on the research associated with a Nobel Prize connected with ANU.

The first tapestry, completed in April of last year, celebrated Sir John Eccles and his work on the ionic mechanisms of the nerve cells. The second, completed in July, focussed on Professor Peter Doherty and Professor Rolf Zinkernagel and their work on cell mediated immune response. The third tapestry, completed in November and unveiled in December, celebrates the Nobel Prize winning work of Howard Walter Florey. Florey's prize was awarded in 1945 'for the discovery of penicillin and its curative effect in various infectious diseases'.

The process of creating the tapestries required considerable research.

"It's been a great pleasure working on this commission," said Ms Kirk, who is also the Head of the Textiles Workshop at ANU School of Art. "During the process I have met many interesting people and discovered areas of our university that I was previously unaware of.

"Like most people, I knew of penicillin from school science projects, looking at bread mould under the microscope. Also, being brought up on a farm, I was familiar with the penicillin that was used to treat cows and sheep, a pale yellow liquid in an old-fashioned glass jar. But, for the Florey tapestry I needed much more specific information. The finished tapestry couldn't depict any old bread mould.

"I discovered the John Curtin School of Medical Research Museum with its fascinating photographs and accompanying texts. The images made me think of the time before penicillin when even a simple cut could lead to death through an infection. Here in Australia today we no longer see these kinds of festering, untreated wounds. We have greatly benefited from antibiotics and now take them for granted. These thoughts formed the basis of the concept that links the three tapestries - the importance of the work in its time and its ongoing relevance , even when the research has gone far beyond the first discoveries."

To represent the original research, she selected a small photograph displayed in the museum showing the action of penicillin on mould in a Petri dish. Around this she presented a scanning electron micrograph of the mould itself.

"I had imagined that getting a contemporary image of penicillin would be simple," she said. "This was not so. I was directed to CSIRO where Rosemary White showed me text book illustrations but said that nobody was now interested in working with penicillin.

"Eventually an ideal mature growth specimen of Penicillium was sourced from the Canberra Hospital. Roger Heady at the ANU Electron Microscope Unit photographed this and produced beautiful, detailed images, which I have used as reference for the coloured part of the tapestry image.

"Each tapestry has taken three months of full time work at the loom, and this Florey tapestry has been the most complex to weave, because of the small repetitive black shapes spread across the entire image. The tapestry has to read as if the coloured image is in the background and the black superimposed over it. To make this happen, technically the coloured weft had to be woven at each side of every black shape then the black weaving was stitched in place. In this way it has been like meshing two jigsaw puzzles together or weaving two tapestries at the same time.

The third and final Nobel tapestry by Valerie Kirk celebrating the science of Howard Florey and development of penicillin.

Valerie Kirk at work on the second of the three tapestries.

"Green was another challenge in this tapestry. You only have to look at nature to see how many variations of green there are - grey greens, yellow greens, sharp acid greens, soft woody greens. I went to the Victorian Tapestry Workshop in Melbourne to select the weft yarns for the tapestry. There I held my original artwork against cops of yarn to select colours, but even with a standard range of 350 colours, the greens were not exactly as I wanted. To achieve precise colours I plied 12 - 16 strands of fine wool on each bobbin, changing the combination of colours to give subtle blends and smooth transitions from one colour or tone to another. This gives a natural organic feel through the colour mixing in the tapestry."

While some might find the thought of weaving a tapestry for months a challenge, Ms Kirk found the experience a joy.

"The time spent absorbed in the project was so precious, unburdened by the clutter of admin and bureaucracy," she says. "This has been a great project from beginning to end. My thanks go to everyone who has been involved in the planning, research, staff replacement in textiles, hanging and presentation of the tapestries."

The three Nobel tapestries now adorn the walls of University House.

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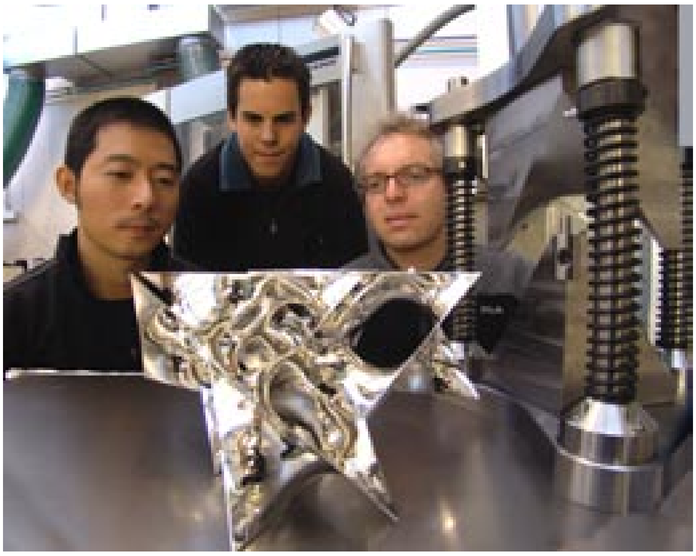
The art of minimal surfaces

by Tim Wetherell

What began as an interest in reflective surfaces led one artist to make connections all across the ANU campus.

Eric Hu began to investigate the artistic potential of reflective surfaces during his Honours year at the ANU School of Art. His early works explored the fascinating effects of internal reflection within spheres which he painstakingly crafted in gilding metal then electroplated with silver. Although Mr Hu was able to create some beautiful works, such as My Kaleidoscope 4, he felt that the single viewing point offered by spheres was restricting. Consequently, when Mr Hu enrolled for a Masters Degree the following year, he began to research more exotic shapes such as those formed when a soap film fills a loop of twisted wire.



(From the left) Eric Hu, Gareth Crook and Gerd Shroeder look at a sculpture built out of minimal surfaces.

It was at this point that Mr Hu began a very productive interaction with Applied Mathematicians Mr Gerd Schroeder, Professor Stephen Hyde and Dr Tim Senden at the Research School of Physical Sciences and Engineering (RSPSE). They too were interested in soap films because surface tension tries to pull the film into a shape that has the minimum possible energy. But the science of surfaces can take one far beyond a single film cell. There are a whole family of possible surfaces, some of which offer the potential to create intertwined double labyrinths. These surfaces are interesting to scientists because they are found in many physical systems including human lungs where the fluids of air and blood need to intertwine over a vast area without actually mixing.

The mathematical surface that particularly caught Mr Hu's artistic eye was an infinite periodic minimal surface known as the diamond surface. Part of its beauty comes from the fact that it consists of two identical, intertwined labyrinths, which can potentially extend out to infinity. However recreating these elegant shapes in solid metal presents a tremendous technical challenge.

Although Mr Hu was able to make small surfaces by hammering metal sheet, this process didn't lend itself to making multiple interlocking cells, which was the direction in which Mr Hu's work was leading. To overcome this, Eric and the math-ematicians designed a minimal-surface press using a 3D computer model. They then had the faces of the press generated in plastic at the University's rapid prototyping facility, with the help of Mr Gilbert Riedelbauch at the Computer Art Studio.

To make the press durable enough to withstand repeated use, Mr Hu then worked with the Sculpture department to cast perfect replicas of the faces of the press in bronze. Using this bronze press, he was able to create a series of cellular minimal surfaces that could be assembled into a portion of the diamond surface.

Mr Hu's work on these surfaces earned him the offer of an exhibition at Sydney's Object Gallery. In order to compliment the smaller works in this show, Eric, has begun work on a large-scale minimal surface sculpture. This required a new press on a much grander scale so Mr Hu took the project to the RSPSE Mechanical workshop. Using Mr Schroeder's mathematical model of the surface and Mr Gareth Crook's expertise in 3D CNC machining, the team was able to create a monster press, capable of withstanding the 30 tons of pressure needed to crush thick metal sheet into the minimal surface cells.

Eric Hu with a purpose built press at RSPSE.

Having finished fine tuning the monster press Mr Hu is now generating large numbers of surface cells and the sculpture is well on the way to completion. Eric's final work, and that of two other ANU silversmiths, can be seen at the Window space, Object gallery in Sydney from 25 March to 7 May 2006.

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Professor Stephen Hyde (left) and Gerd Shroeder demonstrate some of the amazing properties of diamond surfaces using models produced by the rapid prototyper.

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