CSEM's

Materials Monthly

April 2004

Making materials matter

Chips off the old rock

If humans were to vanish tomorrow and aliens attempted to reconstruct our history based on the artefacts we left behind, which artefact might inform them the most about what we were and how we developed? If it was the most common artefact that humans have used over our two-million-year-plus evolutionary history, then the answer would be our stone tools. Flaked stone artefacts comprise the great majority of artefactual remains in the archaeological record.

▲▲ Oliver Macgregor with the experimental apparatus for producing artificial stone flakes.

Because of this prevalence, it's archaeologists rather than aliens that are using stone flakes to reconstruct our past. Oliver Macgregor is one such researcher. He's a doctoral student based in the ANU School of Archaeology and Anthropology. Oliver has found that by applying a little materials science to the interpretation of stone flakes that it's possible to extract a lot more information about the people who created them.

Oliver's approach is to drop steel ball bearings onto slabs of glass cut at different angles to test how they'll fracture. Glass is a hard and brittle material with similar mechanical properties to the materials from which stone artefacts were produced.

Written in stone

Stone artefacts are produced by creating fractures through a body of stone to detach pieces of stone, referred to as flakes. The production of stone artefacts is a reductive technology in that the removal of successive flakes from a rock, referred to as a core, reduces the core in size as more and more material is removed.

Carrying out successive reduction on an artefact allows the knapper (the term used to describe people who make stone tools) to extend the artefact's use life, either by producing flakes which can be used as tools, or re-sharpening a dulled working edge.

"Viewing reduction as a means of extending an artefact's use life enables archaeologists to use variability in the shape of flaked-stone artefacts to answer behavioural questions concerning the human group who produced them," says Oliver. "Differing degrees of reduction, for example, have been correlated with group mobility and the availability of raw materials."

Consequently, there's a need to develop methods of measuring the extent to which an artefact has been reduced. Methods developed so far include measuring the area from which flakes have been removed, and the length and curvature of the flaked edges.

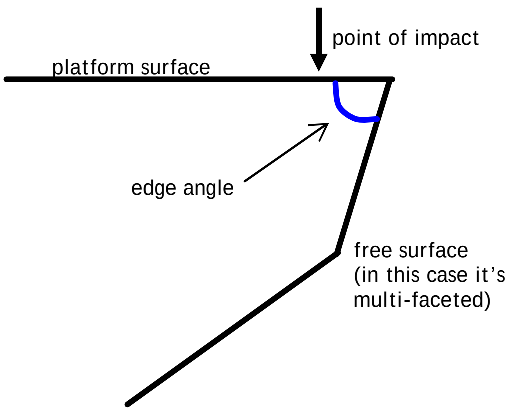
Experimental studies have also been used whereby a controlled force is used to strike flakes from a standardised core to determine the effect of a particular variable on the fracture process and flake morphology. Variables that have been considered include the angle of strike, the magnitude of force, the point at which the force is applied, the shape of the core and the material of the core.

Platform and edge

"Controlled experimental investigations, however, is still a very new field of archaeological science," says Oliver. "There are many important questions still to be answered. My current controlled investigation seeks to refine what we already know about the connection between the mass of the stone flakes and platform thickness and edge angle."

The platform is the surface of the core to which the force is applied to produce a

(Continued on page 2)



▲▲ Figure 1: the two most important factors in determining the mass of a resulting flake are the thickness of the platform and the edge angle

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Chips of the old rock

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fracture. The edge angle is the angle between the platform surface and the free surface (see figure 1).

"We know from controlled experiments that the two most important factors in determining the mass of a resulting flake are the thickness of the platform and the edge angle," says Oliver. "However, the existing model is based on experiments performed on cores with flat, undifferentiated free surfaces whereas archaeological artefacts normally have multi-faceted free surfaces.

"Indeed, multi-faceted free surfaces are extremely common on stone artefacts," explains Oliver. "A stone core which has a flake struck from it will generally have a multi-faceted free surface composed of the original free surface of the core, and the new surface created by the flake-producing fracture. Any flake-producing fracture initiated from the same platform will, therefore, propagate behind a multi-faceted free surface."

"My research will hopefully determine the degree of difficulty connected with removing flakes from cores with different free surfaces, both flat and multi-faceted.

"I'll also be looking at different edge angles. Controlled experiments have shown that the greater the edge angle of an artefact the more difficult it is to remove a flake. However, once again, the experiments were only done using flat free surfaces which begs the question: does a multi-faceted free surface compound the effect of the edge angle on the difficulty of removing a flake.

"A subset of this research is the consideration of what happens when the knapper creates a problematic fracture such as a sudden termination. Does the knapper throw the core away and start again or does he/she persist with a difficult core. The decision, of course, depends on how difficult it is continue as opposed to how available a fresh core might be. My research will go some way determining an 'index of difficulty' of working with abrupt terminations."

Breaking glass

Oliver's controlled experiments involve striking flakes from glass cores by dropping a ball bearing onto the platform surface. To ensure that the force with which the ball bearing strikes the platform is constant, it's dropped from an electromagnet held at a constant height above the core. Cores are held immobile in a vice throughout the procedure.

For example, the experimental series that Oliver set up to examine the effects of abrupt terminations used ball bearings that were 20 mm in diameter, and weighed 32.2 grams. The height from which the ball bearings were dropped was 900 mm. The force of impact was therefore the same throughout all the experimental series. The angle at which the ball bearings impacted the platform surface of the core was held at a constant 20 degrees from a line perpendicular to the platform surface.

"The work on abrupt terminations is a good example of the value of these controlled experiments," says Oliver. "The experiments confirmed that the presence of an abruptly terminated scar on the free surface of a core can have a dramatic effect on the paths of fractures travelling through the core.

"The experiments also made it apparent that the effect of the scar depended upon the distance into the core at which the fracture was initiated. On all the scarred cores, there existed a threshold of platform thickness, below which fractures hinged or stepped to meet the distal corner of the scar, and above which they traveled past the scar, terminating further down the core. In other words, a pre-existing scar on the free surface of a core can only be removed by applying the force at a point above this scar threshold."

"The experimental results demonstrate that abrupt terminations have the potential to cause problems for the reduction process, in that they increase the probability that subsequent flakes struck from the same platform will also terminate abruptly. To reduce the problems occurring as a result of abrupt terminations, knappers could employ strategies of reduction which decrease the chances of abrupt terminations occurring, or which increase the chances of successfully overcoming the problems posed when abrupt terminations occur."

An index of difficulty

"There are many stone artefact collections around the world," says Oliver. "But it's only through controlled experiments such as these that we're able to build universal models that allow us to measure to some degree the comparative difficulty involved in producing these artefacts. When combined with other information about the human groups that created these artefacts, these models allow us to examine a collection and extract fresh information about the cultures from which they originated."

Of course, this isn't just about cracking slabs of glass. The results of Oliver's experiments will help to refine a flake mass predictor model that he will then apply in the interpretation of a collection of stone artefacts.

"That's really the acid test," says Oliver. "Is the information that I'm collecting providing us with a useful tool that helps us better analyse the stone artefacts that comprise the bulk of our archaeological record? That's the next stage in this research, however I'm quietly confident that this approach will greatly increase the sophistication of the measurement of artefact reduction, which will in turn allow archaeologists to make statements about the selective pressures operating on human groups."

The work has involved collaborations with the Department of Engineering and assistance from the Department of Earth and Marine Sciences, and the Research School of Earth Sciences.

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Glass slabs are used as rock mimics. ▶▶

Reinforced bulk metallic glass

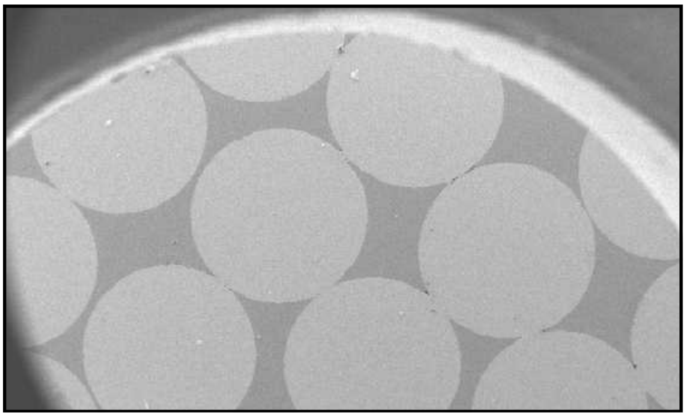
In the last decade a new class of wonder materials called metallic glasses have begun to emerge from materials labs around the world. They exhibit properties of incredible strength and elasticity, but small cracks can lead quickly to catastrophic failure. Now efforts are being made to reinforce the material with tungsten.

Conventional metals have a crystalline structure in which the atoms are lined up in neat, orderly arrays; the bulk of these standard metals typically consists of small regions of aligned atoms, called grains, and the boundaries between them. Within metallic glass, however, atoms are packed together in a somewhat random fashion, similar to that of a liquid. Research indicates that the prized physical properties of metallic glasses (also known as amorphous metal) arise in large part from their lack of grain boundaries, which can serve as points of weakness.

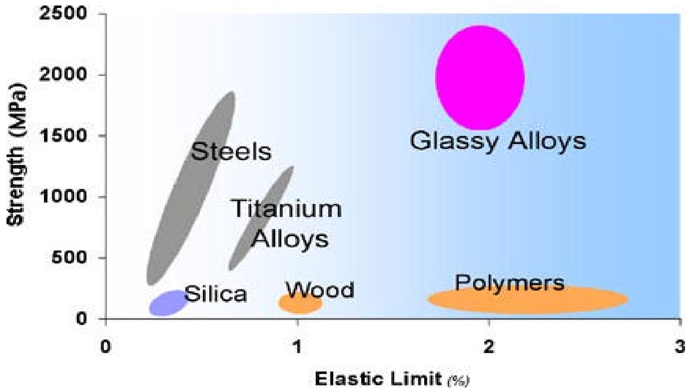
Unlike conventional metals, which are usually cooled until they fully solidify, metallic glasses must be cooled very rapidly and very uniformly to freeze their random atomic pattern in place before crystallisation occurs due to the nucleation and growth of crystal grains. When this phenomenon were first being explored, some 40 years ago, the only way to extract heat fast enough to maintain the metal's random state was to keep the material very thin. It was produced by splat cooling in which droplets of molten metal were quickly frozen on a cold surface. Continuous amorphous metal ribbons less than 0.1 millimeter thick could also be formed at a cooling rate of 1 million°C per second. The ribbons were wear-resistant and possessed interesting magnetic properties but the high fabrication cost meant it never found any commercial application.

▲▲ Wang Gang with samples of metallic glass

Over the past decade, methods have been developed to produce metallic glasses in bulk based on mixes of zirconium, magnesium, aluminum, and iron. Early approaches to bulk fabrication were mostly empirical in nature, but researchers gradually began to understand



▲▲ A cross resection through the BMG rods. The circles are tungsten wire



▲▲ Metallic glasses are in a class of their own.

(Figure from www.its.caltech.edu/~vitreloy/development.htm)

that the correct choice of elemental constituents would lead to amorphous metals amenable to cooling rates as slow as 1 - 100°C per second. These slower cooling rates mean that large parts can be fabricated. Furthermore, many of these metallic glasses remain stable against crystallisation when heated to temperatures somewhat above their glass-transition temperatures.

One of the general guiding principles to designing alloys that form bulk metallic glasses is to pick elements with dramatic differences in size, which leads to a complicated structure that crystallises less easily. A beryllium atom, for example, is much smaller than a zirconium atom. One common mix of these new bulk metallic glasses is two-thirds zirconium, one-fifth beryllium, and the remainder split among copper, titanium, and nickel.

These new bulk metallic glasses exhibit high strength-to-weight ratios and hardness, extreme springiness and rebound characteristics, and good acoustic-dampening properties. They're being considered for a range of applications including golf-club heads, amour piercing ammunition casings and surgical prosthetics.

Unfortunately, the Achilles heel of this wonder material is that it has an extremely low resistance to crack-initiation—the propagation of a crack once it has formed. When it fails, it fails catastrophically. To fill this hole a range of strengthening materials are being considered to add to the bulk metallic glass (BMG), and one technique being investigated is rods of BMG reinforced with tungsten wire.

Doctoral student Wang Gang is visiting ANU from the School of Materials Science and Engineering, Harbin Institute of Technology, China, to test a range of samples of tungsten-reinforced BMG. While here he will be characterising these samples using the University's impressive array of equipment, especially its transmission and scanning electron microscope facilities. Wang Gang will be based in the Dept of Engineering until the end of November. His project involves cross-campus collaboration between the Department of Engineering and the EMU, RSC and RSES.

For more info on Wang Gang's project please contact Zbigniew.Stachurski@anu.edu.au

Opportunities

Careers in nanotech

Looking for new openings in nanotechnology? Check out the 'working in nanotechnology' website. It claims to be the world's most comprehensive site for employment, education and training in nanotechnology. Check it out at:

http://www.workingin-nanotechnology.com/

Wolf Foundation Prizes

Five or six prizes of $100,000 each are awarded annually to outstanding scientists and artists, irrespective of nationality, for achievements in the interest of mankind and friendly relations among peoples.

In science, annual awards are made in agriculture, chemistry, mathematics, medicine, and physics.

Applications close 31 August 2004

More information:

http://australia.infoed.org/new_spin/spin_prog.asp?14735

http://www.aquanet.co.il/wolf/wolfnomn.html

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Working with Harvard

The Harvard Club of Australia has announced a new award - the Australia-Harvard Fellowship - to cover visits by senior Harvard researchers to Australian institutions. There are two awards in 2004 - up to $40,000 each.

Science researchers who have collaborative research interests with colleagues at Harvard University that "have the ultimate goal of commercialising world saleable Australian products and services" should apply.

Applications close 31 May 2004.

More info: http://www.harvard.org.au/
(or contact Fellowship Secretary, John Turner, email ahf@harvard.org.au)

Jolly good fellows

Twenty* of Australia's leading scientists were honoured in March by election to the Australian Academy of Science. (*Usually 16 are elected however to commemorate its 50th Anniversary Year, the Academy has elected an additional four Fellows.)

Election to the Academy recognises a career that has significantly advanced, and continues to advance, the world's scientific knowledge. Once again, the ANU is well represented in this year's crop with the election of three members of staff (two from RSC and one from RSES). Congratulations from CSEM.

ANU's new Fellows are:
Prof Martin Banwell, RSC, Chemical synthesis and biologically active natural products
http://rsc.anu.edu.au/RSC/ChemResearch/Chemists/banwell.html

Prof Christopher Easton, RSC, Amino acid free radicals; supramolecular chemistry and molecular recognition
http://rsc.anu.edu.au/RSC/ChemResearch/Chemists/easton.html

Professor Malcolm McCulloch, RSES, Application of isotopic and trace element geochemical methods to better understand the impacts of both climatic and anthropogenic processes on the Earth's environment.
http://rses.anu.edu.au/environment/eePages/eePeople/eeMalcolmMcCulloch.html

For a full list of new fellows, see
http://www.science.org.au/media/newfel2004.htm

New Endeavours

High performing scholars from around the world will be able to carry out research in Australia under a new Government funded fellowship programme.

In their inaugural year, the Endeavour Postgraduate and Postdoctoral Research Fellowships will provide funding of up to A$25,000 for 21 international scholars in any field of study, to conduct research at Australian universities for four to six months. In 2005, the number will almost double to 41 fellowships.

Participants will come from Asia, Europe, the Middle East and North and Latin America.

Applications for the Fellowships close on 28 May 2004 with the successful candidates undertaking their research in Australia between August 2004 and June 2005.

It is expected that awards offered under the Endeavour Programme will enjoy similar prestige to that of the US's Fulbright Programme and the UK's Rhodes Scholarships, our two main competitors in international education.

**More info:
www.dest.gov.au/International/Awards/endeavour.htm**

How big is nanotech?

Just how big is Australian research in nanotech? Based on newspaper headlines you'd be forgiven for thinking we're leading the world. It's nigh on impossible to see the truth through the hype, but the Australian Academy of Science has recently posted the results of a landmark benchmarking study on where Australia stands in the world of nanotech research.

The bibliometric analysis found that Australia produced 1.41 per cent of the world's nanotechnology publications from 1980-2003 and 1.49 per cent from 1998-2003. This is lower than for science as a whole, where Australia produced 2.0-2.4 per cent of the world's science publications between 1990-99. The number of Australian nanotechnology publications has increased fairly steadily each year since 'taking off' around 1990.

A citation analysis of Australian nanotechnology publications indicates that Australian nanotechnology papers are being published in relatively high impact journals, and are receiving a higher than average citation rate in those journals.

The percentage of world science publications relating to nanotechnology has been increasing linearly since 1990, indicating that nanotechnology is rapidly becoming an important area of research throughout the world. The percentage of Australian science publications that contain nanotechnology is also increasing, indicating that nanotechnology is becoming an important area of research in Australia.

However, it appears that this increase is less rapid than for the world as a whole. Australia's share of world nanotechnology publications peaked in the mid to late 1990s but has decreased slightly since then, suggesting that while Australia's nanotechnology capability is increasing, we have not been keeping pace with the rest of the world in the past 5 years. From an analysis of the publication outputs of leading nanotechnology countries', nanotechnology appears to be a smaller sector of science in Australia compared with all the other leading nations or regions.

Australia's publication outputs are consistent across the major nanotechnology sub-fields and key topics, indicating a broad level of expertise in all areas of nanotechnology. Australia ranks 7th in the world (excluding the USA) in US nanotechnology patents, based on a number of different ranking criteria, not just absolute number of nanotechnology patents.

Australia has no formal national nanotechnology initiative, although an informal network is currently in the process of developing a formal structure. Other countries have formal national nanotechnology initiatives that not only pour (in some cases) large amounts of money into nanotechnology R&D, but also serve to focus and direct the national effort. Australia risks falling behind if a similar organisation is not set up here. However, there is significant government investment in Australian nanotechnology research from the ARC and CSIRO, plus funding from state governments.

Various ARC-funded nanotechnology projects that commenced in 2002 and 2003 have been allocated a total of A$53,013,909 over their project lives.

The benchmarking results were 'peer reviewed' by sending preliminary results to leading Australian nanotechnology researchers for comment, along with a survey aimed at identifying world-leading researchers in the field, who subsequently were also surveyed. While the size of the sample was small, the survey confirmed that Australia has a small number of 'world leaders' in nanotechnology, but in some sub-fields the international researchers found it difficult to name Australian researchers. This is consistent with the bibliometric result that Australia's involvement in nanotechnology is not keeping up with the rest of the world.

Which all goes to show that there are numbers and there are numbers. This study suggests we are slipping in nanotech whereas the study quoted in the next story suggests things have never been better.

For the full report, please visit http://www.science.org.au/policy/nanotech.htm

Robust good health

A new analysis suggests that Australian research is in robust good health. The number of papers produced by Australian researchers has doubled over the last 20 years, from 10,000 papers in 1981 to over 20,000 in 2002.

And the impact of these papers has also increased. The average number of citations has increased from 2.6 to 4.2 over the same period.

The analysis, conducted by the company Thompson Scientific, has been loudly trumpeted by the Federal Government. It identifies the 'hot' areas of Australian research as the space sciences and geoscience. It is in these disciplines where papers by Australian authors are cited well above the international average rates.

More info: http://www.isinet.com/press/8219329/

AMTN's Canberra man

Ulrich Theden is the new State Manager for the Canberra Office of the Australian Materials Technology Network. The Office will operate out of CSEM.

Ulrich is a familiar face around ANU as he was formerly the Business Development Manager for the Photovoltaics Group, Centre for Sustainable Energy Systems.

The AMTN position is part time with Ulrich working Mondays, Wednesdays and Thursdays.

More info: Ulrich.Theden@anu.edu.au

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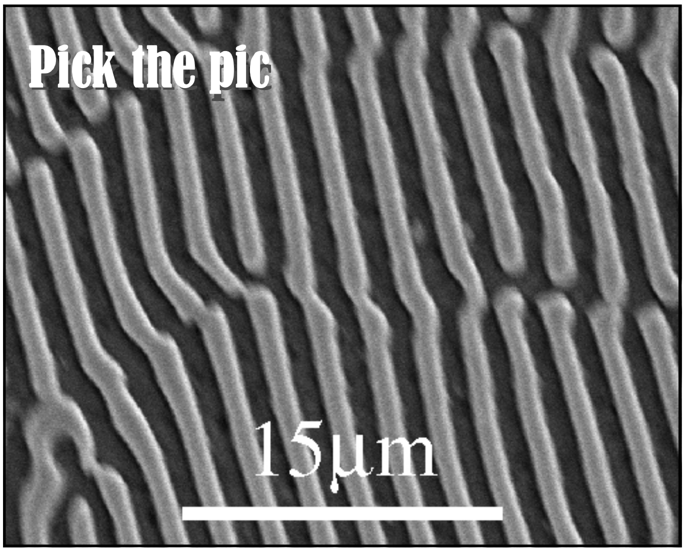


Ripples in the alloy

This SEM shows a eutectic alloy of aluminium (approx two thirds) and copper (approx one third). In the liquid state the two metals are soluble in each other but when cooling is complete, the grain of the solid alloy consist of two distinguishable metals which can be seen under a microscope to be like a layer of one metal on top of a layer of the other metal. A eutectic alloy solidifies like a pure element, at a single temperature, not over a temperature range.

This image was taken by Prof Clyne 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). For an explanation of how eutectic alloys work, see http://www.soton.ac.uk/~pasr1/eutectic.htm#page1 (a website created by the Uni of Southampton).

Capturing the spirit of Stromlo

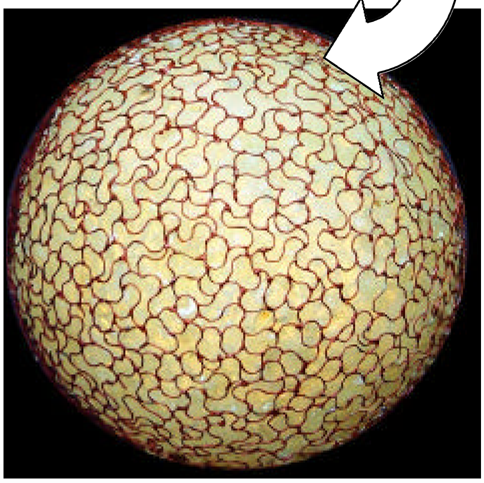
Most of Mt Stromlo Observatory was reduced to cinders in the wildfires of 2003. Materials Monthly discussed how this transformed many of the materials that made up the Observatory in our July 2003 issue. Now, an innovative new project sponsored by the ANU National Institute of Physical Sciences is seeking to build a massive art installation using bits of the fire damaged telescopes. The installation will resemble part of a giant orrery* with a Sun made from fragments of the telescope lenses and a planet formed with carbonised wood and ash set in epoxy resin

It's called the Stromlo Orrery Project and it's being put together by Tim Wetherell. Phase one of this project is the construction of the giant Sun that will be approximately two metres in diameter. The glass fragments that will coat it range in size from a few mm to several cm in size. Removing the glass from the site proved quite difficult due to the dangerous state of the burnt out buildings and the presence of some toxic materials.

More info: http://wwwrsphysse.anu.edu.au/admin/php/orrery/orrery.php

*An orrery is a mechanical model of the solar system. It's named after Charles Boyle, Fourth Earl of Orrery (1676-1731), for whom one was made.

◀◀ Artist Tim Wetherell with a model of one of the globes that will form part of the final orrery. The final globe will measure 1.5 m in diameter. (On the wall behind him is a sketch of what the final installation may look like.



Tim with glass shards collected from the shattered Stromlo site. These will be incorporated in to a giant 2m Sun that will form the centre piece of the installation.▶▶

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