ANU Centre for Science and Engineering of Materials

# Materials Monthly

*Making materials matter*

May 2002

# Research of a Lifetime

***by Catherine Atkinson***

What's the 'lifetime' of an electron or a hole in a silicon wafer? The term 'lifetime' refers to the length of time an electron spends moving around the wafer when excited by a ray of light. Accurately measuring a lifetime is important in determining the electrical properties of silicon wafers used for solar cells (for background on how solar cells function, see the box on *Electrons and Solar Cells* on page 5.).

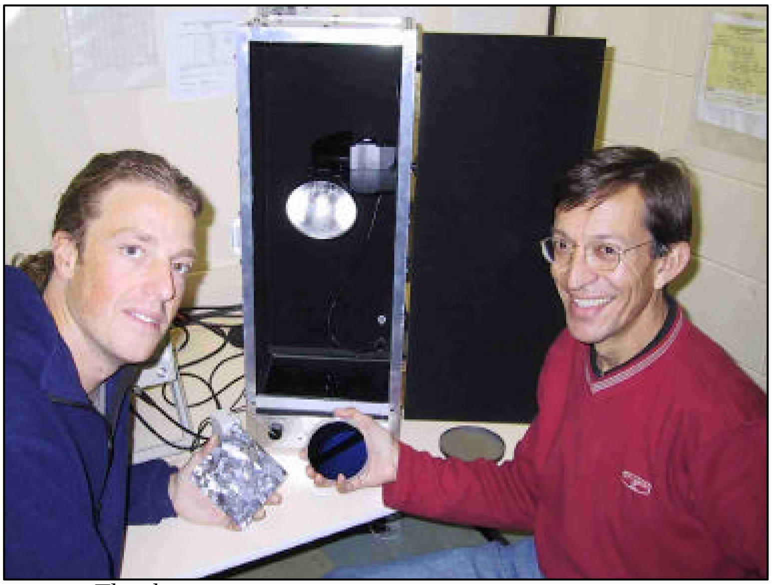
Over recent years, researchers from the Department of Engineering at the ANU have been helping to develop a powerful new system for measuring the 'lifetime' of electrons and holes. The new approach is called the quasi-steady-state photo conductance (QSSPC) technique. QSSPC is based on simple principles, but is very robust and accurate.

QSSPC uses a magnetic coil coupled to the silicon wafer to measure the total number of electrons moving around the wafer. At the same time, a solar cell is used to measure the intensity of the light the wafer is exposed to. This allows the rate at which electrons become excited to be determined. In a steady state the number of electrons becoming excited is equal to the number of electrons recombining with holes. Knowing the total number of excited electrons present and the rate at which electrons are becoming excited the average lifetime of electrons is able to be calculated.

When QSSPC-derived lifetimes are graphed, defects and impurities display their own signature curve. The shape of the signature can be used to identify the type of impurity. The magnitude of the signature can indicate the amount of the impurity present. This means that QSSPC can be used as a means of 'lifetime' spectroscopy to determine which impurities are present in the cell material. It can also be used to quantify the effects of defects and impurities on the efficiency of solar cells.

Dr Daniel Macdonald is part of a small group lead by Dr. Andres Cuevas in the Department of Engineering, FEIT. He is using the QSSPC technique to develop lifetime spectroscopy methods to identify impurities such as iron. Because these impurities have a dramatic effect on the lifetime of electrons in silicon wafers, even minute traces can be important. Other techniques are not sensitive enough to detect minute traces, but lifetime spectroscopy can detect impurities as low as one part in $10^{12}$.

*Continued on page 5*



▲▲ Daniel (and the left) and Andres hold different kinds of silicon wafer. Behind them in the black box is the QSSPC apparatus.

## Inside this MM



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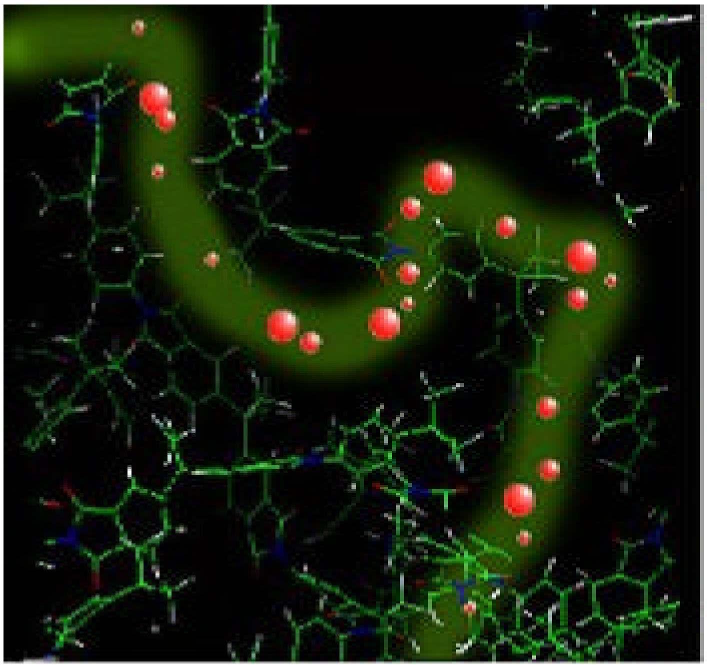
# Catalyst

**Ideas, news and opportunities**

## Nanofilters



A team of Australian and US scientists have just announced a world breakthrough in the use of membrane technology to filter and separate various gases and vapours.

The new filtration media are created by combining organic polymers (normally used to make membrane filters) with inorganic substances - in this case a mist of silica nanoparticles. The team discovered that this combination gives the membrane a quite extraordinary ability to separate large organic molecules from the gases in which they might be floating.

A team includes scientists from CSIRO, University of Texas at Austin, North Carolina State University and MTR, Menlo Park California.

"This new technology will have a wide range of applications," predicts Dr Anita Hill from CSIRO. "These include processes such as biomolecule purification, environmental remediation, seawater desalination and petroleum chemicals and fuel production. Traditionally, this sort of filtering has mostly been done by distillation, which is often very costly in terms of equipment and energy use.

"Membranes are attractive as filters because they are a low-cost, energy-efficient, green technology - but their uses for separating gases have so far been limited by the lack of the right sort of membranes to yield pure products, with high speed and low operating cost while remaining stable."

As a rule, the more selective a polymer is at extracting a pure gas, the less permeable it tends to be - and the more expensive it is to use.

The new nanoparticle-enhanced polymers promise to deliver both high filtering efficiency and high throughput, making them much more cost-efficient.

**More information:**
**http://www.csiro.au/index.asp?type=mediaRelease&id=Nanospace**

## Look mum, no wires!

A team at Johns Hopkins University in the US has developed a prototype chip that uses light instead of wires as an interface.

Professor Andreas Andreou, laboratory director, said: "We have developed a very fast and cost-effective way of getting data on and off a chip without using wire. It really promises to revolutionise how computer systems for homes and businesses are put together."

By adding a layer of synthetic sapphire to a semiconductor wafer and bonding microdetecters on to the sapphire, light transmissions are made possible. An optical receiver is attached to the sapphire layer and converts the light signal back into an electrical one compatible with the chip's electrical circuits.

The signal is transformed into light and beamed through the sapphire substrate via a tiny laser. Microlenses and other optical components, manufactured on the chip, collect the light beam and guide on the chip or, using an optical fibre, move it to another chip.

At its destination, the light enters a high-speed optical receiver circuit that converts the stream of photons into a stream of electrons suitable for interfacing with other computer components.

By using optical signals, the researchers believe a signal could move 100 times faster than it does along a metal wire.

The optoelectric interface circuits require much less power because the sapphire substrate is an insulating material, not a semiconductor.

This interface could significantly improve the internal transfer rate among chips in computers. The prototype can shunt information on and off the chip at 1 Gbps. The current components of the prototype are 0.5 µm wide, but the researchers believe that the next generation will have features as small as 0.1 µm. At that size, the design has the potential to run at 5 Gbps.

**More information:**
**http://www.electroline.com.au/elc/newsletter.asp**

### Words of substance

*It is really quite amazing by what margins competent but conservative scientists and engineers can miss the mark, when they start with the preconceived idea that what they are investigating is impossible. When this happens, the most well-informed men become blinded by their prejudices and are unable to see what lies directly ahead of them.*

**Arthur C. Clarke**

# Working with ion beams

The Ion-beam Modification and Analysis of Materials (IBMAM) Group operate some of the most sophisticated ion-beam facilities in the world. Located within the ANU Research School of Physical Sciences and Engineering (Department of Electronic Materials Engineering), the IBMAM Group undertake a broad range of research activities ranging from fundamental studies of ion-solid interaction processes to application-specific materials science studies employing ion-irradiation and/or ion-beam analysis.

Materials studies include: the production and interaction and of defects in ion-irradiated semiconductors; irradiation induced property changes, the synthesis of novel material structures, and application specific studies such as quantum-well intermixing; impurity gettering; and many others. These programs are supported by ion beam analysis techniques such as Rutherford backscattering and channeling analysis, and elastic recoil detection analysis (ERDA).

The Group's ion beam work is centred around state-of-the-art accelerator facilities, including two ion-implanters based on a 150 kV (single-ended) and a 1.7 MV (tandem) accelerator and a versatile ion-beam analysis machine based on a 1.7 MV tandem accelerator. The 14MV tandem accelerator, operated by the Nuclear Physics Department, is also used for a range of high-energy, heavy-ion beam studies.

The group offers a full range of ion-implantation services including:

▷ **Species:** Most elements with the exception of the inert gases.

▷ **Energies:** Ion energies in the range 15 keV to 10 MeV, depending on species.

▷ **Temperature:** Sample can be heated or cooled (77 – 850K) during implantation.

▷ **Area:** Implant areas are typically less than 4cm x 4cm but larger areas can be accommodated if required.

**More information: Rob.Elliman@anu.edu.au or**

**http://wwwrsphysse.anu.edu.au/eme/IBMAM/index.html**

## 175 kV Ion Implanter

This a 'low' energy ion implanter (pictured below) is used for routine ion implantation and ion-beam modification of materials research. This machine uses a SNICS II ion source to produce negative ions. These are accelerated to a maximum energy of 175 kV before being mass analyzed. They are subsequently electro-

## 1.7 MV Tandem Accelerator for Ion-Beam Analysis

This machine is used for routine ion-beam analysis of materials, including Rutherford backscattering spectrometry which provides compositional analysis of thin film materials as a function of depth. Ion channeling is also employed for the analysis of single-crystals, including many semiconductors, to provide additional information about the crystal-

## 1.7 MV Tandem Accelerator for High Energy Ion Implantation

A high current, high-energy NEC tandem accelerator for ion-implantation and ion-beam modification of materials research (pictured below). This machine uses a SNICS II ion source to produce negative ions. These are mass analyzed and accelerated to high velocity (maximum energy of 1.7 MeV) before passing through a gas stripper to produce a range of positive ions for subsequent acceleration. Selected ions are electrostatically scanned over a defined area on the

sample. Samples can be heated or cooled during irradiation.

## 14 MV Tandem Accelerator for High-Energy, Heavy-Ion Beam Analysis

The 14MV accelerator is used for studies of ion-solid interaction processes and ion-beam analysis of materials. These activities are collaborative between the Departments of Electronic Materials Engineering and Nuclear Physics. In terms of analysis using ion beams, the major development over recent years has been the development of heavy-ion elastic recoil detection analysis (HIERDA) as a routine analytical tool for thin-film and near-surface materials analysis. HIERDA now complements existing analytical facilities by providing quantitative analysis of low atomic number elements, such as H, C, N, and O. Recent experiments have concentrated on improving the performance of the position sensitive gas-ionization detector and on the analysis of thin-film photonic materials.

Local landmark: towering over ANU is part of the 14MV accelerator, a facility run by Nuclear Physics and EME. ▶▶

# Positions vacant

## Australia

**Research Fellow/Maths Modeller (photochemical) (closes 24/5/02)**
RSPhySE/CRES, ANU
http://www.anu.edu.au/hr/jobs/academic.html#915/02

**Postdoctoral Fellow/Protein Dynamics (closes 10/5/02)**
Dept of Physics, ANU
http://www.anu.edu.au/hr/jobs/academic.html#969

**Postdoc Fellow/Semiconductor Materials (closes 24/5/02)**
RSPhySE, ANU
http://www.anu.edu.au/hr/jobs/academic.html#952

**Scientific Programmer/Tandetron Accelerator (closes 24/5/02)**
ANSTO, Sydney
http://www.ansto.gov.au/info/vac/vac2002/v02033.html

**Numerical Modeller/Environmental Fluid Dynamics (closes 17/5/02)**
ANSTO, Sydney
http://www.ansto.gov.au/info/vac/vac2002/v02030.html

**Hydrogeologist (closes 17/5/02)**
ANSTO, Sydney
http://www.ansto.gov.au/info/vac/vac2002/v02032.html

**Graduate Careers/scientists, engineers (closes 23/5/02)**
DSTO, Adelaid, Melbourne, Canberra, Sydney
http://www.dsto.defence.gov.au/

## Overseas

**Professor/Nano-sciences and Technology (closes 31/7/02)**
Florida International Uni, USA
http://www.mrs.org/career_services/classified/ads/florida.html

**Chair/ Materials Science and Engineering (closes 1/7/02)**
Georgia Institute of Technology
http://www.mrs.org/career_services/classified/ads/georgia.html

**Chief/Exposure Assessement (screening begins 15/6/02)**
National Institute for Occupational Health, USA
http://www.mrs.org/career_services/classified/ads/niosh.html

**MSc studentship/Lasers in micro-machining (closes 23/9/02)**
Uni of Hull, UK
http://jobs.ac.uk/jobfiles/IJ182.html

**Engineer Doctorate/Plasma Systems for Thin Film (30/8/02)**
Uni of Manchester, UK
http://jobs.ac.uk/jobfiles/IJ117.html

**Course Director/Fluid Dynamics (closes 7/6/02)**
Uni of Cambridge, UK
http://jobs.ac.uk/jobfiles/IJ059.html

# For the Diary

◄✧► **Seminar: How can materials science assist archaeolgical research in the understanding of ceramic shards? Tony Flynn (FEIT)** — **14 June**
3 pm, Manning Clark Lecture Lt 4, Manning Clarke Centre, ANU. Enquiries to Amanda Kennedy on 6125 0470

◄✧► **Seminar: Conservation approaches to excavated metal objects** — **18 June**
**Canberra Archaeological Society Lecture: David Thurrowgood.**
7.30 pm, Manning Clark Lecture Lt 6, Manning Clarke Centre, ANU. Enquiries to Sam McKay on 6161 0467

◄✧► **Interact 2002** — **21-25 July**
Interact 2002 is the first combined conference and exhibition conducted by the Royal Australian Chemical Institute's Analytical Chemistry Division,Environment Division, the NSW Group of Pharmaceutical Sciences, The International Chemometrics Society and the Australasian Ecotoxicology Society
University of Technolgy, Sydney
http://www.pco.com.au/interact2002/

◄✧► **WCPT4** — **21-25 July**
**World Congress on Particle Physics.**
Sydney
http://www.wcpt4.com/

◄✧► **ICNDST8** — **21-26 July**
**8th International Conference on New Diamond Science and Technology**
University of Melbourne
http://www.conferences.unimelb.edu.au/icndst-8/

◄✧► **1st Materials Science Forum on Future Sustainable Technologies** — **17-20 September**
University of Ausberg, Germany
http://www.amu-augsburg.de/matforum/

(Continued from page 1)

# Research of a lifetime

Metals such as iron are bad news for solar cells, but Daniel is also examining the role some metals may play in enhancing the efficiency of solar cells. Some metals can offer stepping stones for the excitation of electrons. Light too weak to impulse electrons all the way to the high energy state may still effectively contribute to climbing these stepping stones, thus assisting the absorption of infrared radiation and a more effective utilisation of the solar spectrum. This is known as the impurity photovoltaic effect, and the search is now on for impurities with just the right combination of properties.

## Electrons and solar cells

The working day is not an easy one for an electron in a solar cell. Excited by the Sun's energy, electrons move quickly and randomly around the silicon wafer. The holes they leave behind in their excited state also move around the cell. Some electrons may happen to venture beyond a critical point in the cell known as the *p-n* junction. The *p-n* junction is a one way valve, and once it's crossed it is difficult for an electron to pass back through. A concentration of electrons on one side of the junction gradually builds up and opposite charges develop on either side of the cell. Once beyond the junction the easiest way for an electron to return to rest on the other side of the cell is via an external circuit. Placing a load in such a circuit is how electricity is harnessed in a photovoltaic system.

For an electron, the journey within the silicon is fraught with peril. Fast moving electrons may succumb to trapping where they are forced to rest at the site of a defect, and are prevented from their random dash across the cell. Others may fall victim to recombination with holes as they pass near impurities present in the silicon. While trapping is only temporary, recombination permanently puts an end to an electron's across-the-cell adventure, and therefore reduces the efficiency of the solar cell in converting sunlight to electricity.

For further information on the Daniel's research and the Centre for Sustainable Energy Systems, contact Daniel@faceng.anu.edu.au or telephone 02 6125 8567; or Andres Cuevas on Andres@faceng.anu.edu.au.

◀◀ Daniel with the QSSPC apparatus

# Materials Grab Bag

## Materials Excellence

Congratulations to Dr Mark Humphrey from the Department of Chemistry on being the co-recipient of the prestigious David Syme Research Prize. The Prize, run from the University of Melbourne, was established in 1904. It's awarded biennially for the most important contribution to Biology, Chemistry, Geology or Physics. Preference is given to original research of value to the industrial and commercial development of Australia.

▲▲ Dr Mark Humphreys

Mark has been recognised for making substantial and significant contributions to two areas of organometallic chemistry over the past couple of years. First, he has focused the attention of materials organometallic chemists on the non linear optical (NLO) properties of metal acetylide systems (following his earlier studies demonstrating their superiority over the established ferrocenyl class of complexes). His recent work has shown that organometallics can have similar performance to organics with the additional virtue of novel forms of 'switchability'.

Second, he has organised polymetallic cluster modules into 'polycluster' systems with both saturated (non-conducting) and unsaturated linking units, simultaneously delineating factors controlling processability and optical limiting properties.

As a result of these studies, organometallic-based materials may have uses in a variety of applications including optical communications, data storage and laboratory optical device protection.

For more information on the David Syme Research Prize, see http://www.science.unimelb.edu.au/about/awards/Academic.html#Syme

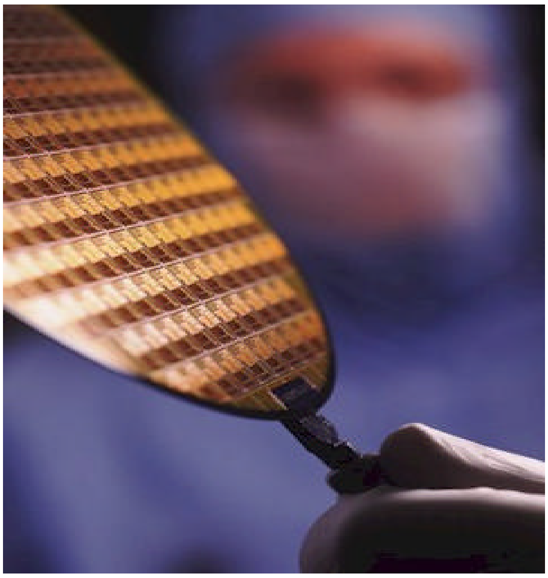
PS: Some of this research was carried out under the CSEM's umbrella involving collaboration between Mark's synthesis group in the Department of Chemistry, Graham Heath in the RSC, Marek Samoc and Barry Luther-Davies at the Laser Physics Centre at RSPhysSE, and quite a few co-supervised students.

## Stunning images?

The international magazine of materials science and engineering, *Materials Today*, is looking for stunning images relating to materials research to adorn the cover of their December 2002 issue. Have you got anything that fits the bill? If so, visit their website (http://www.materialstoday.com) and let them know about it. Besides making a high profile cover, the winner also gets one year's electronic access to the Encyclopedia of Materials Science & Engineering. CSEM would also be very interested in seeing what you've got.

## MM webspotting: silicon

- **Silicon the element**
  http://www.webelements.com/webelements/elements/text/Si/key.html
- **Things silicon can't do**
  http://www.sciam.com/askexpert/astronomy/astronomy28/carbon.html
- **Liver cells on silicon chip**
  http://www.canoe.ca/CNEWSScience0104/23_liver-ap.html
- **Silicon Valley**
  http://www.siliconvalley.com/mld/siliconvalley/
- **Silicon in the Earth's core**
  http://www.geolsoc.org.uk/template.cfm?name=CoreSilicon
- **Silicon and health**
  http://www.healthy.net/asp/templates/article.asp?PageType=article&ID=2067
- **Silicon and metallic microcontamination**
  http://www.esrf.fr/industry/pdf/microelectronics.pdf




# CSEM

ANU Centre for Science & Engineering of Materials

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Depart of Engineering
Department of Forestry
Department of Geology
Department of Physics

**Institute of the Arts**
Materials Workshops

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

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**Please let us know if you wish to be added to our electronic or postal mailing lists.**

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