CSEM: ANU's Centre for Science and Engineering of Materials

Materials Monthly

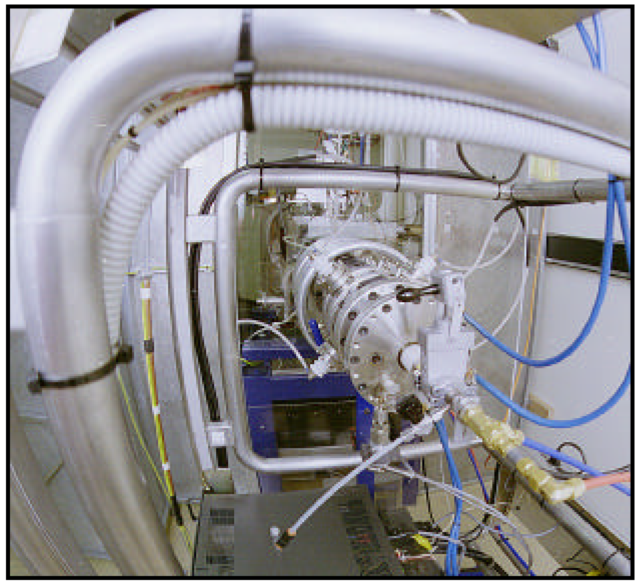
Making materials matter September 2001

Seeing the light with

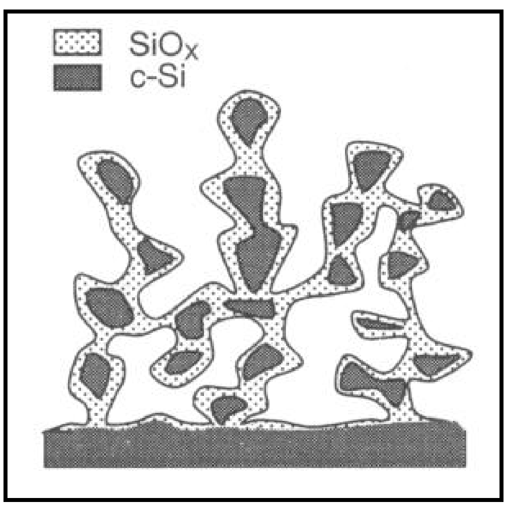
SILICON NANOCRYSTALS

When it comes to high-speed digital electronics, you can't beat silicon. Unfortunately, the same can't be said for optoelectronics because bulk silicon is simply a very inefficient emitter of light. However recent work by scientists at ANU's Department of Electronic Materials Engineering on new and novel forms of silicon is helping to overcome this limitation.

In 1990 it was discovered that porous silicon, a sponge-like form of silicon produced by electrochemical etching of bulk silicon, had the potential to emit light at room temperature. It is believed that this occurs because nanometre-sized crystals of Si found within the porous structure have greater quantum efficiency for optical emission than bulk Si.



The ion source in the low energy ion implanter used by EME to fabricate Si nanocrystal materials.



Schematic diagram of porous silicon showing small crystalline regions with dimensions less than ~10 nm. This material exhibits strong room-temperature photoluminescence due to quantum confinement of carriers in these nanometre -sized regions.

Unfortunately, porous silicon is not easy to craft into devices. It's fragile and tends to absorb surrounding gas and liquid which affects its optical properties. Consequently, an alternative material has been created that possesses the optical qualities of porous silicon. It consists of nanometre sized crystallites of Si embedded in silicon dioxide (SiO_2). These crystallites can be created by precipitating Si in silicon rich SiO_2 (which can be produced by a number of techniques that are compatible with the manufacture of modern microelectronics).

Like porous silicon, silicon nanocrystals emit light over a broad spectral range depending on their size and density distribution. Emission intensity and wavelength depend on the manner in which the nanocrystals are created and can be optimised for

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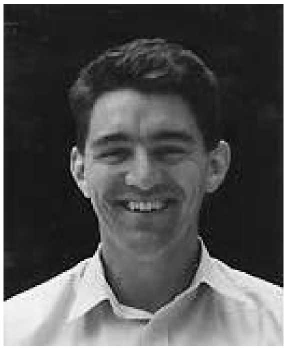

Direct from the Director

Phil Evans
Centre for Science and Engineering of Materials

CSEM appears to be gaining increasing acceptance on campus and externally if recent attendance at our bi-monthly seminar series and interest in our undergraduate program is any guide.

Our last seminar on ‘the light fantastic’, a presentation by Elmar Krausz on the use of laser and optical spectroscopy to probe the structure of materials, attracted around 60 people, the best attended seminar in the last two years (with the exception of Colin Raston’s talk on Green Chemistry; and some unusual circumstances inflated attendance figures for Colin’s seminar!).

Similarly, our stand at the ANU Open Day attracted a lot of attention from many students with the right combination of subjects required for budding materials scientists. As expected, our stream in forensic materials was a drawcard but interest was also shown in the high tech, electronic materials, biomaterials and materials/craft options. Students appeared to find the combination of science, engineering and external units (through UCAN and CIT) attractive, and liked the flexibility and freedom of choices offered by our program.

More surprisingly, CSEM appears to have gained acceptance by the Faculty of Science which provided signage, floor space and acknowledgement in the program. I would like to thank both Nick Welham and David Salt for giving up part of their weekend to promote CSEM’s undergraduate program. I hope you will show your support by attending the next bimonthly seminar on nanomachines which will be given by Denis Evans, the Chair of CSEM’s management committee and Dean of RSC.

Phil points the way to materials science and engineering to a keen young high school student at the recent ANU Open Day.

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Silicon Nanocrystals

particular applications. In principle is should be possible to produce a ‘tunable’ Si-based light source from nanocrystal emission. It might even be possible to build an Si-based laser. In practice, however, our understanding of many of the basic processes remains uncertain and more research is required before working device structures can be developed.

Researchers in the Department of Electronic Materials Engineering (Research School of Physical Science and Engineering) have been actively involved in nanocrystal research for the past 4-5 years. The work, led by Prof. Rob Elliman, has included charge transport in thin oxides containing Si nanocrystals, defect luminescence in ion-implanted silica, and extensive work on light emission from the nanocrystal/silica system.

The next step is to build on this experience and address critical issues involved in the fabrication of light emitting devices based on photo- and electro-luminescence from Si nanocrystals embedded in SiO_2. In particular, the project aims to:

-understand the light emitting properties of silicon nanocrystals

-understand how nanocrystals interact with each other and with impurities, and

-exploit this understanding to fabricate and test a range of novel light emitting device structures.

Success in these studies could pave the way to effectively integrating optoelectronic and electronic devices into one easily manufactured silicon based circuit – and that could lay the foundation for a whole new chapter in the information revolution.

For more information on silicon nanocrystals contact Rob Elliman (Rob.Elliman@anu.edu.au). For more information on the work of Electronic Materials Engineering, check out their website at: http://wwwrsphysse.anu.edu.au/eme/

Laser and Optical Spectroscopy

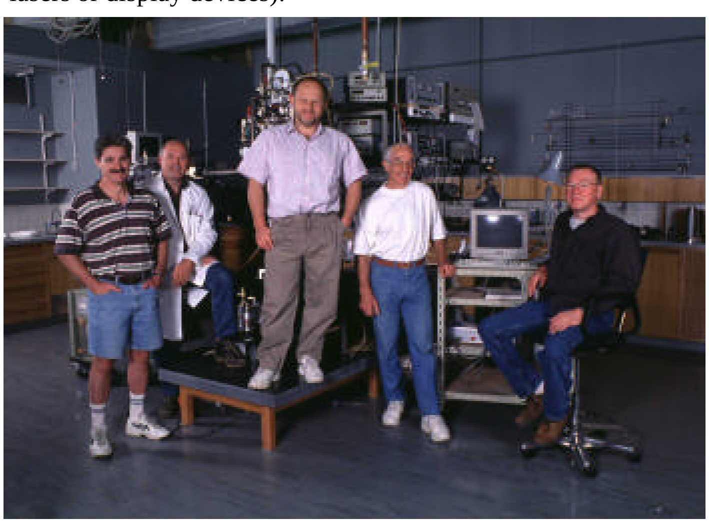
The Laser and Optical Spectroscopy group at the Research School of Chemistry performs spectroscopic measurements on a wide range of materials and systems: organic and inorganic, molecular, ionic, amorphous, crystalline and biological. The group's great strength is in its ability to design, develop and invent special experiments and apparatus to target particular questions. For many years it has developed and enhanced components such as detectors, optics, transient digitisers, lasers, monochromators and superconducting cryostats, and flexibly configured them via computer.

Operating a wide range of conventional optical devices, the group is also equipped with several state of the art lasers. These include N_2/dye, Ar+/dye and Kr+ ion lasers and a scanning single frequency Ti:S ring laser. The group also operates an injection seeded YAG pumped Mirage 500 Optical Parametric Oscillator (OPO) system. The system provides very narrow linewidth light pulses of 10 ns duration, tuneable throughout the visible and near-infrared regions. It does this by splitting second harmonic (530 nm) green light into two different red beams and mixing this with tripled UV (355 nm) light to generate the desired wavelength. Recently the group developed a special f 4 Spectrograph system that's ideal for extremely low level light detection such as is involved with chemiluminescence.

While capable of operating in most spectroscopic areas, the group has a unique capacity to work in the areas of:

- magnetic circular dichroism
- micro-crystal spectrophotometry
- laser selective spectroscopy

As examples of its work, the group, led by Dr Elmars Krausz, has been performing some exciting research on the biochemistry and biophysics of photosystem II, the chemical driver of photosynthesis ; unusual spectroscopic properties (chemiluminescence) of Rubisco, the carbon dioxide fixing enzyme crucial to photosynthesis; the gold-sulfur interaction in biosensor devices; and bistable optical materials that emit laser light at shorter wavelengths than the exciting wavelength (making them useful as lasers or display devices).



◀◀ Elmars and collaborators of the Laser and Optical Spectroscopy group working on Photosystem II, in front of the extremely versatile and high performance MCD facility. From left: Ron Pace, Keith Jackman, Elmars Krausz, Gad Fischer and Tom Wydrzynski. Among other ground breaking discoveries made by the group is that the Photosystem II core engine has significant differences between plants and photosynthetic bacteria.

If you would like to learn more about the activities of the Laser and Optical Spectroscopy group or make use of their spectroscopic expertise and equipment visit their website and make contact.

http://rsc.anu.edu.au/~krausz/laser.html

Some of the equipment available through the group includes:

- **Microcrystal Spectrometer Optics/Systems**
- **Variable Temperature Cryostats**
- **Cryogenic Flow Tubes**
- **Shielded Photomultiplier Housings**
- **Quartz Halogen Lamp Housings**
- **Near IR detectors/optics/cryostats**

The light fantastic

Spectroscopy is the study of how light interacts with matter. By shining a light of known character (wavelength and pulse duration) on a material and then measuring how much of that light is absorbed, emitted or scattered, it's possible to probe the basic chemical and electronic structure of that material, sometimes right down to the single molecule level.

Lasers have revolutionised spectroscopy because they can produce light of unparalleled purity. Laser light can be made of one single colour (wavelength), to a precision better than one part in a billion. Lasers can produce perfectly controlled pulses of light that are large or small. Pulses can be generated that are so short that they match the speed of a chemical reaction. They can initiate them and then be used to monitor the reaction as it takes place. (Chemical reactions occur at the scale of femtoseconds – a million billionth of a second.)

Whether it's analysis, diagnosis or manipulation, spectroscopy is one of materials science and engineering most useful and powerful tools. ANU has a wide range of spectroscopic instruments and research disciplines, with one of the main centres being the Laser and Optical Spectroscopy group based at the Research School of Chemistry.

Positions vacant

Australia

Research Fellow/Luminescence Dating (closes 28/9/01)
RSES/RSPAS, ANU
http://www.anu.edu.au/hr/jobs/academic.html#rses494

Chair of Materials Science, Nanotechnology (closes 12/10/01)
Monash University
http://www.adm.monash.edu.au/sss/pc/jobads/jo_senior.htm

Director, Materials Research (closes 28/9/01)
Australian Nuclear Science and Technology Organisation
http://www.ansto.gov.au/info/vac/vac2001/v70.html

Research Scientist or Engineer/Energy&Recycling (closes 28/9/01)
CSIRO Forest Forestry and Forest Products, Clayton, Vic
Paul Fung on 03 9545, 2487 or email: Paul.Fung@ffp.csiro.au

Research Scientist, Group Leader/Secondary wood products, composite technologies (closes 28/9/01)
CSIRO Forest Forestry and Forest Products, Clayton, Vic
Dr. J Hague on 03 9545 2128 or email: J.Hague@ffp.csiro.au

Research Scientist/adhesives and polymers (closes 28/9/01)
CSIRO Forest Forestry and Forest Products, Clayton, Vic
Dr. J Hague on 03 9545 2128 or email: J.Hague@ffp.csiro.au

Overseas

Tenure-track position/Inorganic chem - materials, (closes 1/11/01)
Princeton Uni, NJ, USA
www.mrs.org/career_services/classified/ads/princeton.html

Assistant Professor/Nano-scale technology (closes 30/9/01)
Toyota Technological Institue, Nagoya, Japan
http://www.mrs.org/career_services/classified/ads/toyota.html

Professorship, Nanomaterials (closes 15/10/01), University of Oxford, UK
http://www.mrs.org/career_services/classified/ads/oxford.html

Research Associates (4 positions)/Materials chem (closes 15/10/01), University of Manchester, UK
http://jobs.ac.uk/jobfiles/ED128.html

Research Associate/Advanced surface coatings (available 28/9/01), University of Cambridge, UK
http://jobs.ac.uk/jobfiles/JB904.html

Postdoc Research Associates (4 positions)/molecular electronic materials (closes 27/9/01)
Imperial College, UK
http://jobs.ac.uk/jobfiles/HK492.html

For the Diary

▶▶▶ **Condensed Matter Theories** — **3-8 December**
25th International Workshop, Belconnen, Canberra
see http://wwwrsphysse.anu.edu.au/theophys/CTP/WORKSHOPS/CMT25_2001/

▶▶▶ **Australasian Conference on Optics and Laser Spectroscopy** — **3-6 December**
Incorporating:
- **▶14th Conference of the Australian Optical Society**
- **▶10th Australian Laser Conference**
- **▶20th Australian Spectroscopy Conference**

Uni of Qld, Brisbane; see http://www.physics.uq.edu.au/acols2001/

▶▶▶ **Microelectronics and Micro-Electro-Mechanical Systems** — **17-19 December**
SPIE International Symposium, Adelaide
see http://spie.org/conferences/calls/01/au/

▶▶▶ **DynamicSummer: Topics in Nonlinear Dynamics & Complexity** — **21 Jan - 1 Feb, 2002**
15th Canberra International Physics Summer School, RSPhySE, ANU
see http://wwwrsphysse.anu.edu.au/theophys/CTP/SUMMERSCHOOLS/2002_SS_DS/index.shtml

▶▶▶ **Technology Convergence in Composites Applications** — **6-9 February, 2002**
ACUN-3 International Composites Conference, Uni of NSW, Sydney
see http://www.materials.unsw.edu.au/events/acun3cover.html

Measuring with light

Did you know it's possible to measure the wavelength of laser light with a quality, hand-held metric ruler? Dr Elmars Krausz showed how at CSEM's August Materials Seminar. By reflecting a laser-pointer light beam off the ruler's sub-millimetre grating (normally found on one end of good metric rulers) you will usually get an interference pattern projected onto a nearby wall. By measuring the distances between peaks of the pattern and the angles of reflection it's possible to calculate the nanometre wavelength of the light (in Elmars' example, using a red laser pointer, it worked out to be 630 nm).

Which is where Elmars' talk, entitled 'The light fantastic' took off. To a large audience from all over the campus, Elmars explained the many amazing properties of light and how spectroscopy can harness these properties to probe the fundamental nature of matter. He also outlined the unique abilities of the Laser and Optical Spectroscopy group, which he leads, and discussed some of their current investigations.

Because spectroscopy straddles the borders of chemistry, physics and biochemistry it's practise is incredibly multidisciplinary. The Laser and Optical Spectroscopy group is keen to discuss joint projects with scientists from anywhere on campus. Elmars is also interested in running a spectroscopy workshop in 2002 for anyone wanting to get more out what the Laser and Optical Spectroscopy group has to offer.

For more information on the Laser and Optical Spectroscopy group see our technology profile on page 3, or visit their website (**http://rsc.anu.edu.au/~krausz/laser.html**) or contact Elmars directly.

Elmars measure red laser light with a metric ruler. ▶

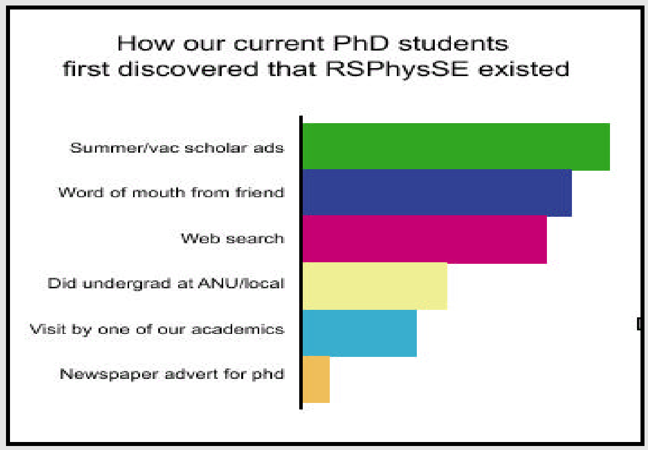
Student Survey

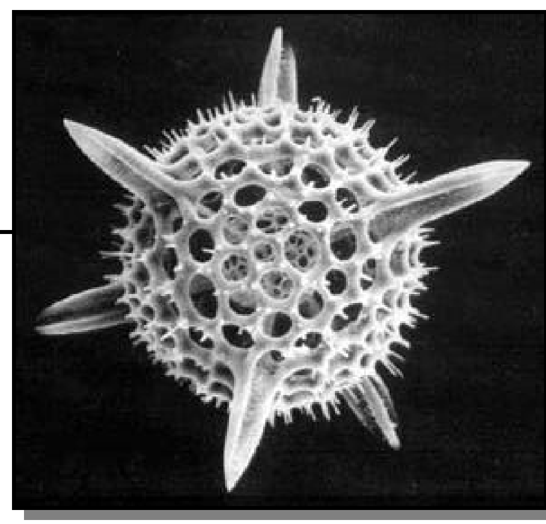
How do PhD students find out about ANU's Research Schools? And having discovered them, what criteria do they use to select one for postgraduate studies?

The Research School of Physical Sciences and Engineering recently put these questions to 50 of their PhD students and came up with some interesting responses. Their survey found that a majority of PhD students first discovered that RSPhySE existed through Summer Vacation Scholar ads (see graph). Close behind this was 'word of mouth' from friends. Closely following this was through their own web search.

When asked why they chose RSPhysSE, the top two responses (equal in number) were because of the facilities that were available and ANU's reputation.

Is this what are other Research Schools are finding? CSEM would be interested in knowing so we can begin to plan our 2002 strategies for attracting quality postgraduates. If you have any ideas, please send them to David.Salt@anu.edu.au





EMU Chapman Course 2001

ANU's Electron Microscope Unit is running a series of em workshops in October. They will be led by Steve Chapman (Protrain). Last year's workshops proved so successful that an extended series is being run this year.

SEM Masterclass (**Tuesday 16 - Thursday 18 October, 2001**)
For SEM users looking to get more out of their machines.

Maintaining and Monitoring the SEM (**Friday, 19 October**)
For SEM users to do basic troubleshooting.

TEM Maintenance (**Monday 22 - Tuesday 23 October**)
For TEM users to do basic troubleshooting.

TEM Operation (**Wednesday 24 - Thursday 25 October**)
For TEM users looking to get more out of their machines.

To find out more about the classes or to book your spot, visit the EMU today: **http://www.anu.edu.au/EMU/index.html** And while you're doing that, check out their new look site.

MM webspotting

Spectroscopy

- ♦ **International Society for Optical Engineering**
  http://www.spie.org/
- ♦ **(JPL's) Atmospheric laser spectroscopy**
  http://laserweb.jpl.nasa.gov/
- ♦ **Laser-Optics – USA**
  http://members.aol.com/WSRNet/laser.htm
- ♦ **Optical Spectroscopy and Neon Lights**
  http://acept.la.asu.edu/PiN/rdg/optical/optical.shtml
- ♦ **The Spectroscopy Net**
  http://www.thespectroscopynet.com/

♦♦ **CSEM's fab *Links* Page**: **http://www.anu.edu.au/CSEM/**

Announcing

CSEM's October Seminar

A Thermodynamic Limit for Nanomachines
THE FLUCTUATION THEOREM OF STATISTICAL MECHANICS

speaker:	**Prof Denis Evans** Research School of Chemistry, ANU
venue:	**Forestry LT, Bld 48,** ANU
date:	**Wednesday, 17 October, 2001**
time:	**4pm** (drinks/nibblies following lecture)

CSEM

Centre for Science & Engineering of Materials

Faculties
Department of Chemistry
Depart of Engineering
Department of Forestry
Department of Geology
Department of Physics
Institute of the Arts
Materials Workshops

Institute of Advanced Studies
Research School of Biological Sciences
Research School of Chemistry
Research School of Earth Sciences
John Curtin School of Medical Research

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Fax: +61 2 6125 0746, Postal: Department of Forestry (#48), Australian National University, ACT 0200
Location: Department of Forestry (#48), Wood Sciences Building, Linnaeus Way, ANU

Materials Monthly comes out in the first half of each month. We welcome your feedback and contributions. Please send them to David Salt, Editor, *Materials Monthly,* care of CSEM. Please let us know if you wish to be added to our electronic or postal mailing lists.

Electronic copies of *Materials Monthly* can be accessed at: **www.anu.edu.au/CSEM**