

# Advanced Materials

The Advanced Materials group is actively engaged in the investigation of the properties and behaviour of materials with topics as diverse as:

- the phosphorus-in-silicon system as a potential basis for spin-based quantum computing
- fundamental properties of rare earth based intermetallics and compounds
- characterization of III-V semiconductors
- monitoring wear in prosthetic joints
- phase analysis of ore refining processes
- sediment transport in river basins and local forests.

In most instances, atomic or nuclear probes are used to study the microscopic properties of the materials involved or their spectroscopic “fingerprints” are used to identify and quantify the amounts of materials and phases present.

The key nuclear probe techniques employed include Mössbauer spectroscopy ( $^{57}\text{Fe}$  as well as rare earth resonances such as  $^{169}\text{Tm}$ ,  $^{161}\text{Dy}$ ) and the very low temperature techniques of Nuclear Orientation (NO) and Nuclear magnetic Resonance on Oriented Nuclei (NMRON). Perturbed angular correlation (PAC) measurements are conducted in collaboration with Prof. Aidan Byrne of the ANU, who was closely associated with the development of the joint radioisotope implanter that is sited here at ADFA. Where radioactive nuclei are employed, they are either diffused into the specimens or implanted using the radioisotope implanter. Sometimes they are activated in situ via neutron irradiation at the Lucas Heights reactor facility. The process of ion implantation is of interest in its own right and is investigated using our School’s radioisotope implanter as well as in collaboration with researchers at other facilities.

The in-house atomic probe technique is that of pulsed and swept-field electron spin resonance (ESR). Although this facility was designed specifically for the quantum computing project, it opens up exciting new possibilities for the study of other dilute magnetic systems.

These microscopic techniques are used in combination with x-ray and neutron powder diffraction, inelastic neutron scattering, specific heat, and bulk DC magnetisation and AC susceptibility measurements.

## Members

### Academic Staff:

**Dr Wayne Hutchison** (w.hutchison@adfa.edu.au) BSc, PhD UNSW, MAIP, MVSA

**Assoc. Prof. Glen Stewart** (g.stewart@adfa.edu.au) BSc, PhD, DipEd. Monash, FAIP

**Dr Heiko Timmers** (h.timmers@adfa.edu.au) BSc Münster, MSc Munich, PhD ANU

### Emeritus Professor:

**Emeritus Prof. Stewart Campbell** (s.campbell@adfa.edu.au) BSc Aberd., MSc Salf., PhD Monash, CPhys, FInstP, FAIP



Pictured is Banchachit Saensunon who submitted his PhD thesis on 31st August 2009. He has now received a Research Publication Fellowship for a period of 3 months from 3 September 2009.

### Visiting Fellows:

**Dr Vernon Edge** BSc PhD DipEd Lond. DipAdmin Canb., ARCS, DIC  
**Assoc. Prof. Dennis Isbister** (d.isbister@adfa.edu.au) BSc, PhD UNSW

### Research Associates:

**Dr Laura Gladkis** (l.gladkis@adfa.edu.au) BSc Argentina, PhD ANU

### UNSW-ANSTO Research Fellow:

**Dr Jianli Wang** (j.wang@adfa.edu.au) BSc Shandong University, China, MSc, PhD Institute of Physics, Chinese Academy of Sciences

Jianli is based at UNSW@ADFA as a joint Research Fellow with the Bragg Institute, ANSTO. Jianli applies neutron scattering in his research with Bragg colleagues.

### Research Fellow:

**Dr Libu Koshy Alexander** (l.alexander@adfa.edu.au) BSc Kerala University, MSc Cochin University of Science and Technology, PhD IIT Bombay

Libu will be working at UNSW@ADFA for at least 2 years on the Magnetic Resonance Program of the Centre for Quantum Computer Technology.

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## Research Students:

**Yanyan Liu** - Research Topic - Nano-scale modification and characterisation of polymer surfaces (started 1 September 2009).

**Anwaar Malik** - Research Topic - Atomic-scale modifications of carbon clusters and nanotubes by ion irradiation.

**Sarah Rittner** - Research Topic - Electron Spin Resonance (ESR) dating of sediments from Pleistocene desert environments.

**Banchachit Saensunon** - Research Topic - A study of the crystal field interaction for two rare earth intermetallic series.

**Hazar Salama** - Research Topic - Structural and magnetic properties of heavy rare earth manganites.

**Jake Warner** - Research Topic - Tracing wear debris pathways from joint prostheses using radioisotopes.

## Recent Graduate Student:

**Nakorn Suwuntanasarn** - Research Topic - Magnetic resonance studies of issues critical to solid state quantum computer, PhD Thesis, 2008.

## Research Collaborators:

**Dr M. Avdeev** (Bragg Institute, ANSTO, Lucas Heights, Sydney)

**Dr A. Balogh** (Technische Universitaet Darmstadt and the Institute for Nanotechnology, Karlsruhe)

**Dr L. Willems van Beveren** (UNSW)

**Prof. G. Bowden** (University of Southampton, UK)

**Prof. M. Brandt** (Walter Schottky Institute, Technical University Munich)

**Dr R. Bramley** (Research School of Chemistry, ANU)

**Prof. E. Brück** (Technical University Delft, The Netherlands)

**Dr S. Butcher** (Macquarie University)

**Prof. A. Byrne** (Department of Nuclear Physics, ANU)

**Prof. J. M. Cadogan** (University of Manitoba, Canada)

**Dr M. Dasgupta** (Department of Nuclear Physics, ANU)

**Prof. S. X. Dou** (Institute of Superconductor and Electronic Materials, University of Wollongong)

**Prof. R. Elliman** (Electronic Materials Engineering, ANU)

**Dr J. Fernandez-Niello** (Tandar Laboratory Buenos Aires, Argentina)

**Prof. Y. Garcia** (the Université catholique de Louvain)

**Dr E. Gauja** (UNSW)

**Dr M. Ghafari** (Technische Universitaet Darmstadt and the Institute for Nanotechnology, Karlsruhe)

**Dr D. Goossens** (Research School of Chemistry, ANU)

**Dr P. Gubbens** (T. U. Delft, The Netherlands)

**Prof. P. Guetlich** (Johannes-Gutenberg University, Mainz, Germany)

**Dr M. Hofmann** (FRM-II, Technische Universität München, Germany)

**Prof. M. R. Ibarra** (Departamento de Física de la Materia Condensada, Universidad de Zaragoza, Spain)

**Dr S. J. Kennedy** (Bragg Institute, ANSTO, Lucas Heights, Sydney)

**Prof. D. Hinde** (Department of Nuclear Physics, ANU)

**Prof. M. James** (Bragg Institute, ANSTO, Lucas Heights, Sydney)

**Prof. K. Becker** (University of Braunschweig, Germany)

**Dr C. Marquina** (Departamento de Física de la Materia Condensada, Universidad de Zaragoza, Spain)

**Dr J. McCallum** (University of Melbourne)

**Prof. K. Mori** (University of Toyama, Japan)

**Assoc. Prof. K.** (Hiko) Nishimura (University of Toyama, Japan)

**Prof. S. Ohya** (University of Niigata, Japan)

**Prof. H. O'Neill** (RSES, ANU)

**Dr R. Pax** (Downer EDI, Mining, Mineral Technologies, Queensland)

**Prof. S. Prawer** (University of Melbourne)

**Prof. D. Ryan** (McGill University, Canada)

**Assoc. Prof. P. Smith** (Trauma and Orthopaedic Research Unit at Canberra Hospital)

**Dr J. Scarvell** (Trauma and Orthopaedic Research Unit at Canberra Hospital)

**Prof. Dr V. Sepelak** (The Institute for Nanotechnology, Karlsruhe, Germany)

**Dr S. Shrestha** (UNSW)

**Dr P. Spizzirri** (University of Melbourne)

**Mr N. Stavrias** (University of Melbourne)

**Dr A. Studer** (Bragg Institute, ANSTO, Lucas Heights, Sydney)

**Dr O. Tegus** (Technical University Delft, The Netherlands)

**Prof. R. Vianden** (Bonn University Germany)

**Assoc. Prof. T. J. White** (Nanyang Technological University, Singapore)

**Dr H. Whitlow** (University of Lund, Sweden)

**Dr M. Wintrebert-Fouquet** (Macquarie University)

**Prof. R. Withers** (ANU)

**Prof. G. H. Wu** (Institute of Physics, Chinese Academy of Sciences, Beijing)

**Prof. Y. Yishikawa** (University of Toyama, Japan)

**Dr D. H. Yu** (Bragg Institute, ANSTO, Lucas Heights, Sydney)

**Dr W-D. Zeitz** (Hahn-Meitner-Institut Berlin)

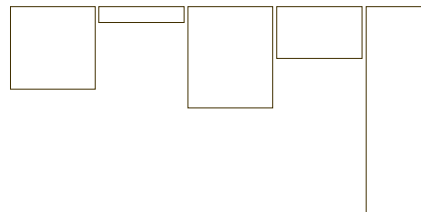
**Dr R. Zeng** (Institute of Superconductor and Electronic Materials, University of Wollongong)

## Current Research

### Characterization of III-V semiconductors with ion beam analysis and radioisotope probes

**Dr Heiko Timmers, with Dr S. Shrestha, Dr S. Butcher, Dr M. Wintrebert-Fouquet, Prof. A. Byrne, Prof. R. Vianden & Dr W. Zeitz**

The increasing demand for wireless communications systems requires faster transistor operating speeds. For many applications, high power, high temperature operation is also needed. The fundamental physical properties of the group III-nitrides GaN and InN suggest that they should outperform Si, and also GaAs, in high-frequency applications. InN is expected to provide the highest operating frequencies while still at high power. In collaboration with Macquarie University in Sydney and others the growth of GaN and InN films is developed to achieve quality material for commercial applications. High precision analysis of the film composition is achieved using Elastic Recoil Detection (ERD) analysis. In addition, in order to study the role of defects and to test



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important processing steps, radioisotopes are implanted into GaN and InN. The subsequent decay of these probes is then observed with Perturbed Angular Correlation (PAC) spectroscopy.

## Elastic recoil detection analysis of materials

### Dr Heiko Timmers with Prof. R. Elliman

Elastic Recoil Detection (ERD) analysis is an ion beam analysis technique which enables the quantitative compositional depth profiling of materials and thin films. In contrast to Rutherford backscattering (RBS) spectrometry, with ERD analysis an individual depth-profile can be resolved for each chemical element. With very heavy ion projectile beams the sensitivity can be extended to span the periodic table. In order to improve the efficacy of ERD analysis, new design concepts for gas-ionisation detectors have been built and tested.

## Fusion dynamics and scattering

### Dr Heiko Timmers with Dr M. Dasgupta & Prof. D. Hinde

The relative motion of two nuclei colliding at energies spanning the Coulomb barrier is coupled to other degrees of freedom of this binary system with the consequence that the binary system encounters a distribution of potential barriers rather than a single barrier. While barrier distributions can be probed in fusion experiments, it has been shown in this work that some information about the barrier distribution may also be obtained with measurements of quasi-elastic and elastic scattering. Experiments on the system  $40\text{Ca}+96\text{Zr}$  suggest that multi-neutron transfer may play an important role in the fusion of heavy systems, as has long been postulated. Quasi-elastic scattering measurements are performed to test this postulate. The results are relevant to the laboratory synthesis of super heavy elements.

## Magnetic properties and magnetocaloric effects

### Emeritus Professor Stewart J. Campbell and Dr Jianli Wang

The overall aim of this project is to investigate the magnetic and structural properties of a wide range of materials using techniques such as magnetization, Mössbauer spectroscopy and neutron diffraction. These projects are undertaken in collaboration with colleagues from Australia, Germany, Belgium and China. A particular emphasis is the search for suitable materials that exhibit giant magnetocaloric effects associated with field-induced and temperature-induced first order magnetic phase transitions. Current materials under investigation include:

- $\text{MnFeP}_{12-x}\text{As}_x$ -based compounds which offer pronounced magnetocaloric effects around room temperature.
- $\text{RMn}_2\text{Ge}_{2-x}\text{Si}_x$  compounds. A giant magnetocaloric effect has been observed around  $T_c(\text{Nd}) = 36\text{ K}$  for  $\text{NdMn}_2\text{Ge}_{0.4}\text{Si}_{1.6}$ . This pronounced effect is associated with the field-induced first order phase transition from antiferromagnetic to ferromagnetic state due to the appearance of Nd magnetic ordering. Other properties of interest include the co-existence of antiferromagnetic and ferromagnetic states with  $R = \text{Pr}$  and valence transitions with  $R = \text{Yb}, \text{Eu}$ .
- $\text{RNi}_2\text{Mn}$  ( $R = \text{Tb}, \text{Dy}, \text{Ho}, \text{Er}$ ). Continuing interest focuses on resolving the crystal structure of these recently synthesized compounds and analyses of the magnetocaloric and critical exponent behaviour at the magnetic phase transitions (e.g.  $T_c = 147 \pm 2\text{ K}$  for  $\text{TbNi}_2\text{Mn}$ ).

- $\text{R}_2\text{Fe}_{17-x}\text{Mn}_x$ . An invar-like effect evident around room temperature accounts for the non-monotonic composition dependence of the lattice parameters at room temperature in  $\text{R}_2\text{Fe}_{17-x}\text{Mn}_x$  compared with other  $\text{R}_2\text{Fe}_{17-x}\text{M}_x$  systems ( $M = \text{Al}, \text{Ga}, \text{Si}$ ) and the related  $\text{R}_2\text{Co}_{17-x}\text{Mn}_x$  series.
- Ni-Mn-Ga-type alloys exhibit enhanced shape memory effects on doping with small amounts of Co. In order to fully understand and exploit this promising behaviour, we aim to determine the magnetovolume effect at the phase transition temperature  $T_m$  and derive the magnetic contribution to thermal expansion. We are also exploring the relationship between magnetic state and nearest Mn neighboring distance in this continuing project.

## Magnetic resonance program

### Dr Wayne Hutchison, Dr Libu Alexander with Prof. Martin Brandt, Dr Jeff McCallum, Dr Greg Milford, Prof. Steven Praver, Dr Paul Spizzirri & Dr Laurens Willems van Beveren

The broad aim of this program is the use of magnetic resonance, directly, for measurements on spin systems which have application as spin based quantum computers (QC). The technique is also applied to investigations of the principal materials and fabrication processes. The emphasis is on electron spin resonance (ESR) studies of the phosphorus-in-silicon (Si:P) system:

### Pulsed ESR for coherence time measurements

One of the attractions of a spin based quantum computer is the prospect of long coherence times. In this project, pulsed ESR is applied to ensembles of phosphorus spins in silicon to explore this experimentally. The spin coherence time is expected to increase with reduction in temperature and of the concentration of both the phosphorus donors and host  $^{29}\text{Si}$  isotope (non-zero nuclear spin). A pulsed ESR system has been developed that can operate in conjunction with an electro-magnet down to 4 K, or with a dilution refrigerator and superconducting solenoid magnet down to millikelvin (mK) temperatures.

### Swept field ESR measurements

Conventional (swept field) ESR is also used to investigate large area Si:P implants (ensembles) produced via implantation of  $\text{P}^+$  and molecular  $\text{P}_2^+$  at the University of Melbourne. Focus continues on examination of various preparation methods with a view to maximise donor activation, as viewed by ESR, and to minimise unwanted charge traps, which are mostly associated with the implantation process itself. Poor donor activation has been observed when using low energy implantation into substrates with surface oxides and this is a non-trivial issue to resolve. So far there is a strong indication that donor electrons are being poached by traps when the donors are placed near to the surface (i.e. the donors are effectively compensated by interfacial traps). There are many approaches to improve the yield of low energy implants and ESR can be applied as a diagnostic.

## Mechanochemical methods and nanostructured materials

### Emeritus Professor Stewart J. Campbell and Dr Jianli Wang

Stewart Campbell has had a long involvement with projects that investigate the phases and reaction processes of mechanochemically treated materials that exhibit novel physical

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properties. Most recently, this work has addressed iron oxides in collaboration with researchers at the Australian National University and, in particular, the structural and magnetic properties of nanoscale spinel ferrites (e.g.  $ZnFe_2O_4$ ;  $MgFe_2O_4$ ;  $NiFe_2O_4$ ) in collaboration with the University of Braunschweig, Germany.

## Mössbauer spectroscopy as a tool for monitoring ore refining processes

**Assoc. Prof. Glen Stewart with Dr Randolph Pax**

Work in collaboration with Dr Randolph Pax of Downer EDI Mining, Mineral Technologies, exploits the phase analysis capability of  $^{57}Fe$ -Mössbauer spectroscopy, in combination with x-ray powder diffraction, for investigating minerals and mineral refining processes. Recent investigations included the reduction stage in the production of synthetic rutile from mineral sands and the processing of local porphyry Cu/Au deposits.

## Nature and influence of the crystal field interaction at the rare earth site in intermetallic compounds

**Assoc. Prof. Glen Stewart, Banchachit Saensunon & Dr Wayne Hutchison with Dr Paul Gubbens, Assoc. Prof. Hiko Nishimura & Prof. Dominic Ryan**

Banchachit Saensunon's thesis work is directed at the influence of the crystal field interaction in rare earth intermetallic compounds. The first part of this project extends a systematic investigation of the crystal field interaction for the isostructural series  $RT_2Si_2$  (R = rare earth, T = Cu, Ni, Co, Fe) to include T = Mn and Cr. The nature of the crystal field interaction in intermetallic compounds is complicated by the presence of itinerant electrons and the purpose of his investigation is to compare how the methods of Mössbauer spectroscopy and inelastic neutron scattering cope with this. The second part of the thesis project is being conducted in collaboration with Wayne Hutchison and Hiko Nishimura and looks at the crystal field origins of intriguing magnetic behaviour of the intermetallic series  $RNiAl_4$ .

## Radioisotope tracing of sediment transport

**Dr Heiko Timmers & Dr Wayne Hutchison with Assoc. Prof. Jacky Croke, Dr Chris Thompson & Dr J. Fernandez-Niello**

Sediment transport along rivers and creeks is an important environmental issue. In this work we have established measurement facilities in the School to quantify sediment transport using the radioisotopes Cs-137, Pb-210 and Be-7. Experiments in progress are relevant to the Fitzroy river basin and local ACT forest management.

## Rare isotopes as tracers of prosthesis debris

**Dr Heiko Timmers & Dr Laura Gladkis with Assoc. Prof. P. Smith, Dr J. Scarvell & Dr J. Fernandez-Niello.**

The incidence of knee replacement surgery in Australia (~30,000 per year) is rising annually by about 10%. The established bearing material for knee prostheses is ultrahigh molecular weight polyethylene (UHMWPE) which is superior to any other. However, particulate wear debris delaminating from the UHMWPE component causes an inflammatory reaction that breaks down the bone, unfastens the prosthesis and can result in severe pain. Due to increasing life expectancy, many patients need several surgical interventions over their lifetime. Knee replacement surgery costs typically \$15,000, imposing a high annual burden of half a billion dollars on the Australian health budget. In this project, we

measure the dynamics of wear debris shedding from UHMWPE in knee prostheses with the unprecedented accuracy of rare isotope tracing and accelerator mass spectrometry.

## Structural and magnetic properties of rare earth multiferroic manganites

**Assoc. Prof. Glen Stewart & Hazar Salama with Prof. Hugh O'Neill, Assoc. Prof. Hiko Nishimura & Prof. Dominic Ryan**

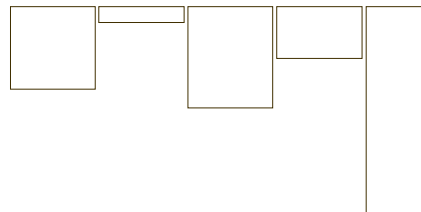
So-called multi-ferroic compounds are of interest to researchers because they exhibit both ferroelectric order (spontaneous electric polarization accompanied by structural distortion) and antiferromagnetism (an ordered magnet structure with zero net magnetization). The interplay between the two effects could possibly be exploited in future magnetic storage devices. As part of her PhD project, Hazar Salama has used  $^{57}Fe$ - and  $^{170}Yb$ -Mössbauer spectroscopy to investigate the local magnetic moments and crystal field interactions in both the hexagonal and orthorhombic phases of ytterbium manganite ( $YbMnO_3$ ). In the case of orthorhombic  $YbMnO_3$ , an intriguing hysteresis effect has been observed in the temperature region immediately below its antiferromagnetic transition. This work has most recently been extended to the two phases of  $TmMnO_3$  employing  $^{169}Tm$ -Mössbauer spectroscopy.

## Recent Research Highlights and Achievements



Dr Heiko Timmers at the Helmholtz-Institute for Radiation Physics in Bonn, Germany.

As part of a Bonn-ANU-PEMS collaboration, funded through a DAAD/ARC grant, from 1-17 July 2008, Heiko carried out experimental work on III-V semiconductors and wear studies on polymers using radioisotope probes. The picture shows a rotating-wheel wear apparatus, designed and built by the PEMS Mechanical Workshop, in operation at Bonn. The apparatus is loaded with a



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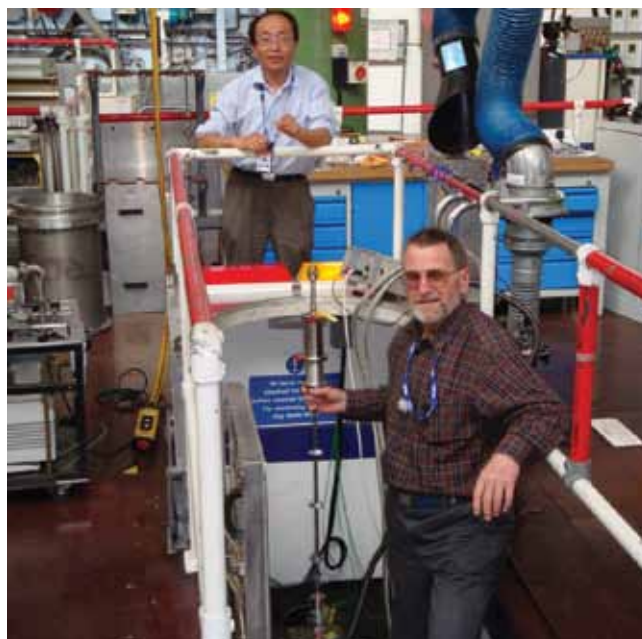
UHMW polyethylene sample prepared with the radioisotope probe Indium-111 at the Bonn radioisotope implanter. The study has shown that over 95% of the polyethylene wear debris is adsorbed onto the actuating wheel and only a small fraction is released to the lubricant.

**Banchachit Saensunon** and **Glen Stewart** met up with Paul Gubbens (a regular guest at the School of PEMS) at the Berlin Neutron Scattering Centre (BENSNC) from 12-16 May 2008 to record inelastic neutron scattering measurements for two intermetallic compounds. The data formed a substantial part of Banchachit's PhD thesis. After the measurements were completed, Banchachit continued on to the Delft Technical University where he met up with Paul Gubbens to discuss planned  $^{166}\text{Er}$ -Mössbauer spectroscopy measurements and presented a departmental seminar. The image below, with Banchachit standing on top of the "NEAT" time-of-flight neutron spectrometer in the BENSNC neutron guide hall, shows just how large the instrument is. The large curved panel conceals an array of several hundred neutron detectors.

In addition to carrying out neutron scattering experiments on the high intensity (Wombat) and high resolution (Echidna) neutron diffractometers at OPAL, ANSTO, **Stewart Campbell** and **Jianli Wang** undertook a series of research projects using neutron instruments at the BENSNC reactor, Berlin (October 2008) and the FRM-II reactor in Munich (May 2009). The particular projects involved Magnetic Phase Transitions in  $\text{PrMn}_2\text{Ge}_{2-x}\text{Si}_x$  and Magnetic Structures and Magnetovolume Effects in Ni-Mn-Co-Ga Shape Memory Alloys. Stewart extended his visit to Berlin to carry out neutron polarization analysis experiments at the ILL reactor, Grenoble France in November 2009. The ILL experiments on a series of nanostructured  $\text{ZnFe}_2\text{O}_4$  materials were undertaken with Dr Shane Kennedy, ANSTO and Dr Michael Hofmann, Technical University Munich.



**Jianli Wang** regularly visits the Bragg Institute, ANSTO and the Institute of Superconductor and Electronic Materials, University of Wollongong to perform detailed characterization of magnetic and transport properties. Their 14 T and 9 T PPMS, 5 T SQUID and differential scanning calorimetry facilities (which together cover the temperature range 1.5 K to 700 K), extend significantly the ranges available at UNSW@ADFA for measurements of physical properties.



[Emeritus Professor Stewart Campbell and Dr Jianli Wang changing the sample on the GEM diffractometer, ISIS.](#)

[ISIS is a world leading pulsed neutron muon source. It is situated at the Rutherford Appleton Laboratory Oxfordshire, United Kingdom.](#)

## Muon spin relaxation studies of iron(II) spin crossover complexes

**Emeritus Professor Stewart J. Campbell**

Iron (II) spin crossover materials that exhibit a change from high-spin ( $S = 2$ ) to low spin ( $S = 0$ ) offer considerable potential for applications in the emerging fields of molecular electronics and nanotechnologies. A productive series of investigations of these compounds in collaboration with the Johannes Gutenberg-Universitaet, Mainz and the Université Catholique de Louvain, Belgium has culminated in a review article published in *Inorganica Chimica Acta*.

## Spin coherence studies using the low temperature, pulsed, electron spin resonance facility

**Dr Wayne Hutchison & Dr Libu Alexander**

Measurements of spin coherence in phosphorus doped silicon are important in the context of quantum computing applications. Our pulsed ESR system, used in conjunction with a dilution refrigerator, is used to make such measurements down to millikelvin temperatures. Recently, using an isotopically enriched  $^{28}\text{Si}$  host together with low donor concentrations, coherence times in excess of 100 ms have been observed.

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## Student Research

### A study of the crystal field interaction for two rare earth intermetallic series

**Banchachit Saensunon** (b.saensunon@student.adfa.edu.au) PhD

**Field of Study: Physics**

The interplay between the crystal and magnetic exchange interaction in rare earth intermetallic is responsible for a range of subtle magnetic structure and bulk behaviour. In this project the  $RT_2Si_2$  (R=rare earth, T=Transition metal) and  $RNiAl_4$  series are investigated using  $^{169}Tm$  Mössbauer spectroscopy and inelastic neutron scattering (INS). The INS measurements were conducted at the Berlin Neutron Scattering Centre, Germany. All of the specimens are prepared at UNSW@ADFA using an argon arc furnace and they are first characterized using x-ray powder diffraction, specific heat, and magnetization measurements.

### Atomic-scale modifications of carbon clusters and nanotubes by ion irradiation

**Anwaar Malik** (a.malik@student.adfa.edu.au) PhD

**Field of Study: Physics**

### Electron Spin Resonance (ESR) dating of sediments from Pleistocene desert environments

**Sarah Rittner** (s.rittner@student.adfa.edu.au)

Transferred from being a Practicum student to PhD student commencing 24 August 2009.

**Field of Study: Physics/Geography**

### Nano-scale modification and characterisation of polymer surfaces

**Yanyan Liu** (y.liu@student.adfa.edu.au) PhD

**Field of Study: Physics**

### Structural and magnetic properties of heavy rare earth manganites

**Hazar Salama** (h.salama@student.adfa.edu.au) PhD

**Field of Study: Advanced Materials**

The multi-ferroic properties of the heavy rare earth manganites, with the composition  $RMnO_3$ , are currently under intense scrutiny. These materials are both ferromagnetic and ferroelectric in the same phase, resulting in higher-order magnetoelectric effects and complex phase diagrams at low temperature. Hazar's PhD project examines the transition of  $RMnO_3$  R=Yb, Tm from the orthorhombic perovskite (o) to the hexagonal (h) phase by high pressure synthesis, the structure and magnetic interactions of both orthorhombic (o) and hexagonal (h) phases and how this affects their magnetic properties. The techniques of  $^{169}Tm$ - and  $^{57}Fe$ - Mössbauer spectroscopy are used to investigate the local magnetic moments and crystal field interactions. The Mössbauer spectroscopy investigations are complemented by magnetic susceptibility and specific heat measurements.

### Tracing wear debris pathways from joint prostheses using radioisotopes

**Jake Warner** (j.warner@student.adfa.edu.au) PhD

**Field of Study: Physics**

With over 600,000 annual total knee replacement operations performed worldwide, the popular choice for the articulating component has been ultra-high molecular weight polyethylene (UHMWPE) due to its very low wear rate. However, polyethylene wear particles from knee and hip prostheses can cause harmful immunological responses, leading to bone resorption and potential loosening of the prosthesis. Due to this aseptic loosening of the prosthesis, revision surgery is required, assuming greater cost and risk for the patient. In order to investigate this wear process, commercial knee simulators are used to actuate against the prosthesis, producing wear debris from the UHMWPE surface. The UHMWPE has been labelled with radioisotope tracers, allowing the tracing of debris pathways. This tracing method will hopefully lead to a better understanding of the tribology of the knee prosthesis and the debris exchange processes, as well as the accumulation of wear debris at various locations in the joint system.

## Research Agreements

### Academic exchange between UNSW@ADFA, School of PEMS and the University of Toyama, Graduate School of Science and Engineering.

Prof. Katsuhiko Nishimura from the University of Toyama is a regular visitor to UNSW@ADFA. His long standing collaborative research work with **Dr Wayne Hutchison** and the Advanced Materials Group was the basis of an agreement for Academic exchange between UNSW@ADFA, School of PEMS and the University of Toyama, Graduate School of Science and Engineering. The agreement was instigated some 5 years ago and was recently renewed.

### Joint agreement between UNSW and ANSTO.

Dr Jianli Wang's position as Bragg- UNSW@ADFA Research Fellow (initially for a 3 year term) is part of this joint agreement. The Bragg Institute, ANSTO is responsible for neutron scattering at Australia's research reactor, OPAL, and aims to be an international leader in neutron beam and X-ray science. Jianli works with colleagues here in PEMS and at the Bragg Institute on developmental and theoretical aspects of modern condensed matter science, particularly magnetism.

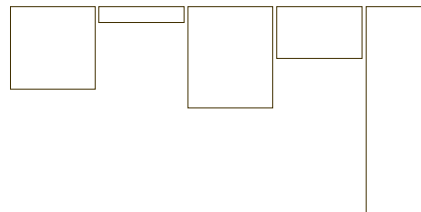
## PhD Opportunities and Scholarships

**If you require any further information, are interested in collaborative research with members of the group, or looking at a potential PhD or Research Masters topic then please contact:**

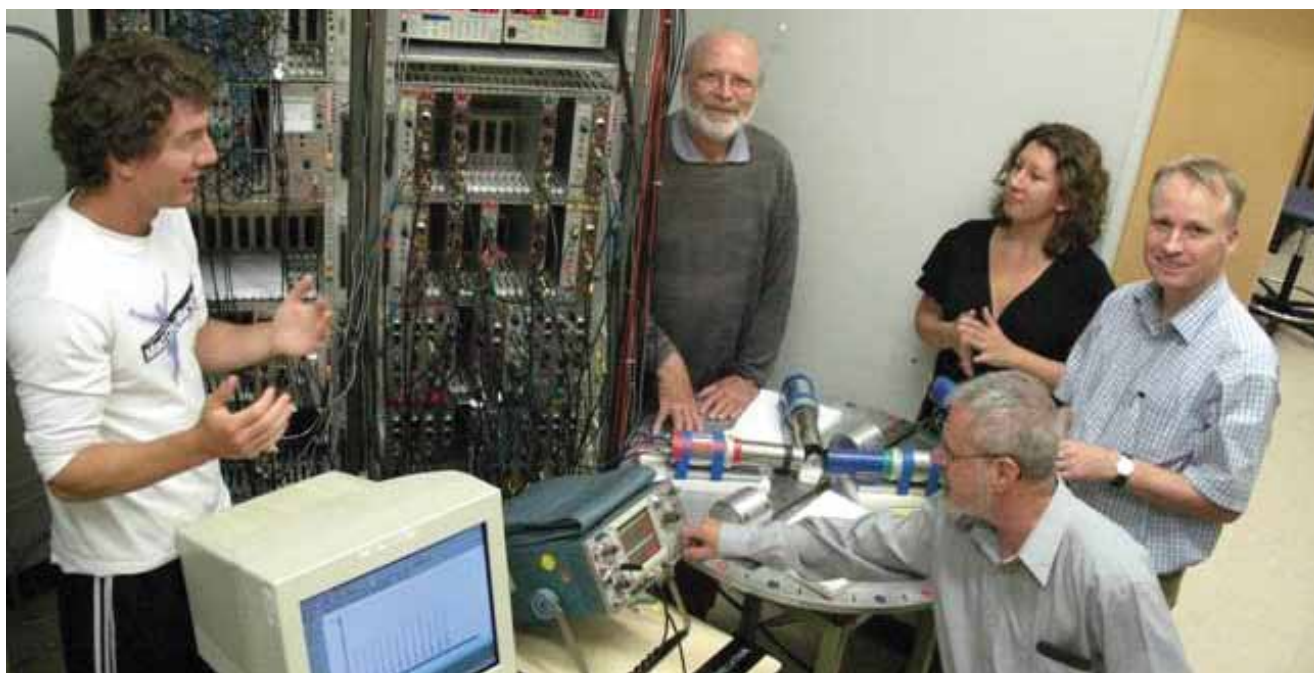
**Dr Wayne Hutchison** (w.hutchison@adfa.edu.au)

**Wayne Hutchison** manages the Magnetic Resonance Program of the Centre for Quantum Computer Technology (see <http://www.qcaustralia.org/organisational.php>)

**Dr Heiko Timmers** (h.timmers@adfa.edu.au)



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One of the two new Perturbed Angular Correlation Spectrometers at UNSW@ADFA produces first results. From left to right: Mr Jake Warner (PhD student), Dr Wolf-Dietrich Zeitz (Visitor to PEMS), Dr Laura Gladkis, Dr Heiko Timmers. In front: Dr William Kemp.

## Major Facilities

- Radioisotope implanter (negative ion, 50-150 keV).
- Two  $^3\text{He}$ - $^4\text{He}$  dilution refrigerators (base temperatures of 6 mK) used as low temperature platforms for: nuclear magnetic resonance on oriented nuclei (NMRON); low temperature nuclear orientation (LTNO); pulsed electron spin resonance (ESR); source and absorber geometry Mössbauer spectroscopy.
- Suite of four  $^{57}\text{Fe}$ - and two  $^{169}\text{Tm}$ -Mössbauer spectrometers (three cryostats 2-300 K; furnaces 300-720 K).
- Pulsed and conventional electron spin resonance (ESR) facilities.
- Sample preparation laboratory (argon arc furnace, tube furnaces, basic glass-blowing facilities, diamond saws & spark cutting, polishing, fume cupboards, hydrogen loading apparatus).
- X-ray diffractometers, vibrating sample magnetometer (0-1 T, 8-300 K) and AC magnetic susceptometer (2-300 K).
- Radioisotope handling laboratory.
- Two new Perturbed Angular Correlation spectrometers at UNSW@ADFA.

In 2008-2009, the impressive suite of research apparatus located at PEMS was augmented through the donation of two spectrometers for perturbed angular correlation (PAC) research by the Hahn-Meitner Institute in Berlin. The gift was facilitated by Dr Wolf-Dietrich Zeitz. The spectrometers complement in particular the radioisotope implanter, which is the ideal preparation tool for PAC.

The method suits research into magnetic and semiconductor materials. During a five months Visiting Fellowship, which has just ended, Dr Zeitz installed the PAC spectrometers and introduced his PEMS colleagues to their possibilities. The quick installation time was made possible through the effective support of the PEMS workshops. Moreover, as in a previous sojourn, Dr Zeitz proved to be a sought-after mentor of postgraduate students and postdocs contributing to tribology (the science and technology of interacting surfaces in relative motion, including the study of friction, lubrication, and wear) work on polyethylene, knee prosthesis wear research and magnetism in nickel. The PAC spectrometers play a particular role in collaborative work on the semiconductors GaN and ZnO which aims to contribute to the development of spintronics (the study of magnetic and electric fields produced by electron spin). This international collaboration involves apart from UNSW@ADFA researchers, scientists and facilities at the University of Bonn and the Australian National University.

## Publications

### In Press

#### Conference - Full paper refereed

**Wang, J.L., Campbell, S.J.,** Studer, A.J., Kennedy, S.J., Zeng R. & Dou, S.X., in press, Magnetic properties of  $\text{Ho}_2\text{Fe}_{17-x}\text{Mn}_x$  – influence of Mn substitution, *Proceedings of the International Conference on Magnetism, ICM2009*, 26-31 July 2009, Karlsruhe, Germany, Journal of Physics, Conference Series.

### 2009 publications

#### Journal – Refereed

**Gladkis, L.G.,** Li, R.W., Scarvell, J.M., Smith, P.N., **Timmers, H.**, 2009, Exploration of the size, shape and abundance of UHMWPE wear particles using atomic force microscopy, *Wear*, 267(1-4), 632-638, doi:10.1016/j.wear.2008.11.024.

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Li, L., Nishimura, K. & **Hutchison, W.D.**, 2009, Magnetic properties and large inverse magnetocaloric effect in single crystal TbNiAl<sub>4</sub>, *Solid State Communications*, 149(23-24), 932-936, doi:10.1016/j.ssc.2009.03.032.

**Saensunon, B., Stewart, G.A.** & Nishimura, K., 2009, Crystal field interaction at the Tm<sup>3+</sup> site in TmCr<sub>2</sub>Si<sub>2</sub>, *Journal of Alloys and Compounds*, 476(1-2), 49-53, doi:10.1016/j.jallcom.2008.09.158.

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**Wang, J.L., Campbell, S.J., Studer, A.J., Avdeev, M., Zeng, R. & Dou, S.X.**, 2009, Magnetic phase transitions in Pr<sub>1-x</sub>Lu<sub>x</sub>Mn<sub>2</sub>Ge<sub>2</sub> compounds, *Journal of Physics: Condensed Matter*, 21(12) 124217-1-124217-11, doi: 10.1088/0953-8984/21/12/124217.

**Wang, J.L., Campbell, S.J., Zeng, R., Poh, C.K., Dou, S.X. & Kennedy, S.J.**, 2009, Re-entrant Ferromagnet PrMn<sub>2</sub>Ge<sub>0.8</sub>Si<sub>1.2</sub> - magnetic properties and magnetocaloric effect, *Journal of Applied Physics*, 105(7), 07A909-1-07A909-3, doi: 10.1063/1.3059610.

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## Conference - Abstract

**Bulatovic, N., Hutchison, W.D., Spizzirri, P.G. & McCallum, J.C.**, 2009, Methods for improving the activation levels of near surface implanted phosphorus donors in silicon, oral presentation, *Handbook of the 33rd Annual ANZIP Condensed Matter and Materials Meeting*, 4-6 February, Charles Sturt University, Wagga Wagga, Australia.

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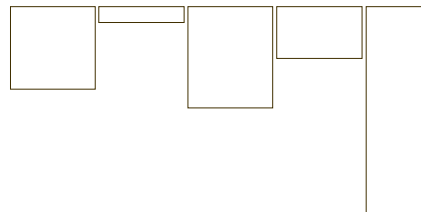
**Gladkis, L.G., Li, R.W., Scarvell, J.M., Smith, P.N., Timmers, H.**, 2009, Exploration of the size, shape and abundance of UHMWPE wear particles using atomic force microscopy, *Proceedings of International Wear of Materials Conference*, Las Vegas, USA, 19-23 April 2009.

**Kennedy, S.J., Campbell S.J., Hoffmann, M., Deen, P., Becker, K.D., Fabian, M., Sepelak, V.**, 2009, Insight to the magnetic character of Zinc Ferrite nanoparticles from neutron polarisation analysis, *Book of Abstracts for PNSXM2009, Polarized Neutrons and Synchrotron X-rays for Magnetism*, 2-5 August 2009, Bonn, Germany.

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**Salama, H.A. & Stewart, G.A.**, 2009, A  $^{169}\text{Tm}$ -Mössbauer spectroscopy investigation of orthorhombic phase  $\text{TmMnO}_3$ , *Handbook of the International Conference on the Applications of the Mössbauer Effect*, Vienna, Austria, p. T09-57.

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**Wang, J.L., Campbell, S.J.**, Hofmann, M., Kennedy, S.J., Zeng, R. & Dou, S.X., 2009, Magnetocaloric effect and phase transitions in  $\text{PrMn}_2\text{Ge}_{2-x}\text{Si}_x$ , *Handbook of the 33rd Annual Condensed Matter and Materials Meeting*, 4-6 February, Charles Sturt University, Wagga Wagga, Australia, p. TP15.

**Wang, J.L., Campbell, S.J.**, Studer, A.J., Kennedy, S.J., Zeng, R. & Dou, S.X., 2009, Magnetic structures and magneto-volume effects in  $\text{Ho}_2\text{Fe}_{17-x}\text{Mn}_x$ , *Handbook of the 33rd Annual Condensed Matter and Materials Meeting*, 4-6 February, Charles Sturt University, Wagga Wagga, Australia, p. WP16.

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**Warner, J., Gladkiss, L.G.**, Smith, P.N., Scarvell, J.M., **Timmers, H.**, 2009, New techniques for quantifying and tracing prosthetic wear, *ACT Young Investigators Forum, The Australian Society for Medical Research*, 2nd June 2009, The Canberra Hospital, Canberra, Australia.

## Invited talks

**Campbell, S.J. & Wang, J.L.**, 2009, (Invited Talk), The magnetism of rare earth intermetallic compounds – a platform for designed magnetocaloric materials, *International Workshop on Electronic Materials and their Applications*; Institute for Superconductivity and Electronic Materials, University of Wollongong, Australia.

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## 2008 publications

### Journal - Refereed

Garcia, Y., **Campbell, S.J.**, Lord, J.S. & Gutlich, P., 2008, Muon spin relaxation studies of iron(II) spin crossover complexes, *Inorganica Chimica Acta*, 361(12-13), 3577-3585, doi:10.1016/j.ica.2008.03.034.

**Hutchison, W.D.**, Chaplin, D.H. & Nishimura, K., 2008, Low temperature nuclear orientation observations of severe neutron activation damage in  $(160\text{Tb})\text{TbNiAl}_4$ , *Hyperfine Interactions*, 177(1-3), 39-43, doi: 10.1007/s10751-008-9619-7.

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**Saensunon, B., Stewart, G.A.** & Pax, R.A., 2008, A combined  $^{57}\text{Fe}$ -Mössbauer and X-ray diffraction study of the ilmenite reduction process in a commercial rotary kiln, *International Journal of Mineral Processing*, 86, 26-32, doi:10.1016/j.minpro.2007.10.004.

**Salama, H.A., Stewart, G.A.**, Ryan, D.H., Elouneq-Jamroz, M. & **Edge, A.V.J.**, 2008, A Mössbauer spectroscopy investigation of h-YbMnO<sub>3</sub>, *Journal of Physics: Condensed Matter*, 20(25), 1-7, doi: 10.1088/0953-8984/20/25/255213.

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**Wang, J., Campbell, S.J.**, Studer, A.J., Avdeev, M., Hofmann, M., Hoelzel, M. & Dou, S.X., 2008, Magnetic structures and phase transitions in  $\text{PrMn}_{2-x}\text{Fe}_x\text{Ge}_x$  ( $x=1.0-1.6$ ) – neutron diffraction and  $^{57}\text{Fe}$  Mössbauer spectroscopy, *Journal of Applied Physics*, 104(10), 103911-103911-12, doi: 10.1063/1.3021096.

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## Conference - Abstract

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**Hutchison, W.D.**, Goossens, D.J., Studer, A.J., Avdeev, M., **Saensunon B.** & **Stewart, G.A.**, 2008, A recent low temperature measurement at OPAL - magnetic structure of  $\text{ErNiAl}_4$ , *Conference Handbook: 7th AINSE/ANBUG Neutron Scattering Symposium, AANSS 2008*, D. Riley et al. (eds), Lucas Heights, Australia, 8-10 December 2008, p. 7.

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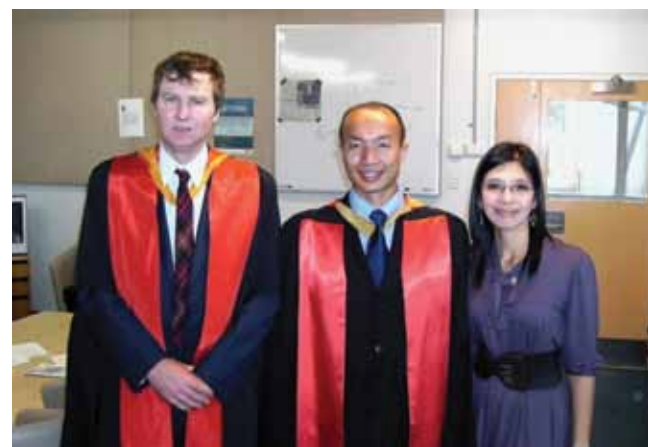
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## Thesis

**Suwuntanasarn, Nakorn**, 2008, Magnetic resonance studies of issues critical to solid state quantum computer, School of Physical, Environmental & Mathematical Sciences, Australian Defence Force Academy, UNSW, PhD Thesis, Available at: <http://handle.unsw.edu.au/1959.4/40263>.



Dr Wayne Hutchison with PhD graduate Nakorn Suwuntanasarn and 'Queenie' at UNSW@ADFA Graduation, December 2008 (Photo credit: K. Badek).

## Grants

### External Grants

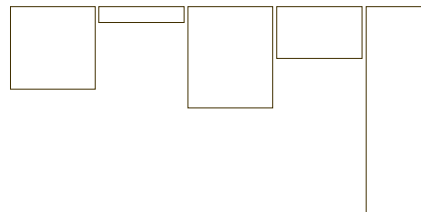
**S.J. Campbell**, Insight to novel spin crossover compounds by MuSR, ANSTO, 2008: \$9,429.

**S.J. Campbell**, G. Kearley, H. Riesen, Structure of  $\text{NaMgAl}(\text{oxalate})_3 \cdot 9\text{H}_2\text{O}$  and neutron spin-echo studies of water flips.; Magnetic nanoclusters in Zinc Ferrites, ANSTO, 2008: \$11,890.

**G.A. Stewart**, Determination of crystal field parameters for the intermetallic compound  $\text{ErCr}_2\text{Si}_2$ , ANSTO, 2009: \$3,400.

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R.G. Clark, G.J. Milburn, A.S. Dzurak, D.N. Jamieson, A.G. White, M. Simmons, T. Lehmann, H. Rubinstein-Dunlop, S. Praver, L. Hollenberg, T. Ralph, J.C. McCallum, C. Pakes, H. Wiseman, G.R. Pryde, J. Twamley, I. Shparlinsky, D.R. MacKenzie, E.H. Huntington, **W.D. Hutchison**, D. Pulford, G. Klimeck, B.C. Saunders, R. Sharp, Centre for Quantum Computer Technology, ARC COE (renewal) 2008-2010: \$10.1M (\$270,000 to WDH UNSW@ADFA).



# Advanced Materials

R.G. Clark, G.J. Milburn, A.S. Dzurak, M.Y. Simmons, A.R. Hamilton, S. Praver, D.N. Jamieson, L.C. Hollenberg, J.C. McCallum, C.I. Pakes, H. Rubinsztein-Dunlop, T.C. Ralph, A.G. White, B.C. Sanders, H. Wiseman, D.R. McKenzie, E.H. Huntington, **W.D. Hutchison**, D. Pulford, R.J. Hughes, P.C. Hammel, B.E. Kane, W.J. Munro & R. Sharp, Centre for Quantum Computer Technology, ARC COE, 2003-2008: \$14.2M (\$425,000 to WDH UNSW@ADFA).

D. Mather, **S.J. Campbell** and 12 co-investigators, Access for Australian researchers to advanced neutron-beam techniques, ARC Linkage, LIEF, Australian Research Council, 2008-2012: \$1,000,000.

**G.A. Stewart**, A Mössbauer investigation of the hexagonal and orthorhombic phases of  $\text{TmMnO}_3$ , AINSE, 2008: \$4,000.

**H. Timmers, L.G. Gladkis**, Dr J.M. Scarvell (University of Canberra) & A/Prof. P.N. Smith (Canberra Hospital), Rare isotopes as tracers of prosthesis debris, ARC Linkage Grant, \$324,000, (2008: \$108,000; 2009: \$108,000; 2010: \$108,000).

**J. Wang & S.J. Campbell**, Magnetic transitions and magnetovolume effects in  $\text{Pr}_{1-x}\text{Y}_x\text{Mn}_2\text{Ge}_2$ , ANSTO, 2008: \$3,985.

## UNSW Grants

**S.J. Campbell, J. Wang** & S.J. Kennedy, The magnetocaloric effect – combining physics and functional materials, UNSW@ADFA Silverstar Award, 2009: \$20,000.

**L.G. Gladkis & H. Timmers**, Bioactivity of polyethylene wear particles, Bruce Milthorpe (UNSW Eng), 2009: \$30,000.

I. Petersen, E. Huntington, C. Harb, G. Milford & **W.D. Hutchison**, Network analyzer, UNSW Major Research Equipment and Infrastructure Scheme (MREIS), 2009: \$67,000.

**H. Timmers**, Dilute magnetic GaN for radiation-hard spintronics memory in strategic defence systems, DSARC Scholarship/BLUEGLASS Ltd, 2009: \$64,881.

**S.J. Campbell**, Access for Australian researchers to advanced neutron-beam techniques, UNSW Capital Grants Scheme, (UNSW + PEMS; \$15,200 + \$4,050)

H. Riesen, **S.J. Campbell** & G. Jackson, Light-induced water flips in crystals: High density optical storage at the molecular level, UNSW@ADFA Silverstar Award, 2008: \$20,000.

## Conference Participation

Members of the Advanced Materials research group attended the *32nd Annual Condensed Matter and Materials Meeting, 2008* at Wagga Wagga. The PEMS troupe, made up of **Rose Ahlefeldt, Natasa Bulatovic, Stewart Campbell, Wayne Hutchison, Hazar Salama, Glen Stewart** and **Jianli Wang**, contributed eight poster presentations and submitted four 4-page manuscripts for on-line publication ([www.aip.org.au/content/publications](http://www.aip.org.au/content/publications)). Although **Banchachit Saensunon** was unable to make it back from Thailand in time to attend, he still managed to win a prize for a poster.

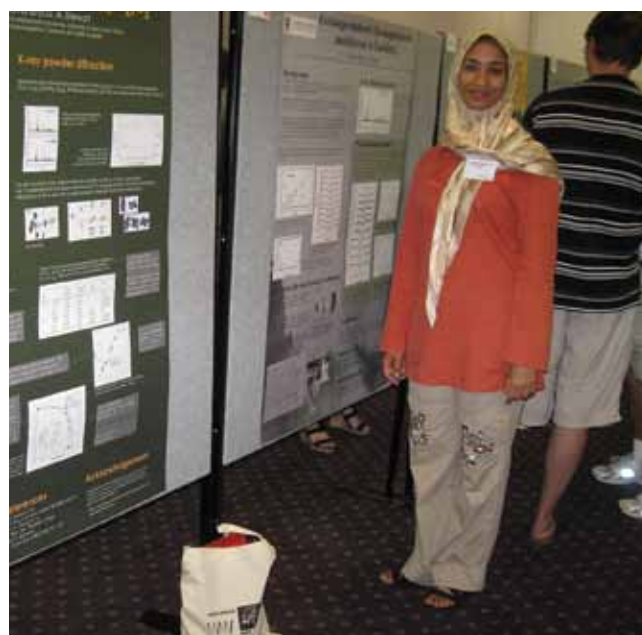
**Stewart Campbell** and **Jianli Wang** presented a poster and a talk at *AANSS2008*, the AINSE ANBUG Neutron Scattering Symposium which was held at Lucas Heights, Sydney from 8 to 10 December 2008.

**Banchachit Saensunon** attended the *Australian Research Network for Advanced Materials 2008 Annual Workshop* held at Deakin University 15-18 December 2008 and presented a poster and short presentation "Crystal field interaction at the  $\text{Tm}^{3+}$  site in  $\text{TmCr}_2\text{Si}_2$ ".

In February 2009, eight members of the Advanced Materials Research Group participated in the *33rd Annual Condensed Matter and Materials Meeting* at Wagga Wagga. They were **Natasa Bulatovic, Stewart Campbell, Wayne Hutchison, Anwaar Malik, Hazar Salama, Banchachit Saensunon, Glen Stewart** and **Jianli Wang**. Both Banchachit and Hazar were awarded prizes for the best student posters in their respective poster sessions.



Jianli Wang and Hazar Salama at the Symposium on Neutron Scattering and Magnetism on the occasion of the 70th birthday of Dr Trevor Hicks, 25th March 2009.



PhD student Hazar Salama was awarded a prize for the best student poster in her poster session.

# Advanced Materials

Jianli Wang and **Stewart Campbell** attended an International Workshop on "Electronic Materials and their Applications" at the University of Wollongong from 19-20 March 2009. While at the workshop, Jianli also took the opportunity to carry out magnetic measurements on some of our new sets of magnetic materials. Access to these sophisticated items of equipment, which operate over wide ranges of temperature (1.5-350 K) and magnetic field (0-14 T) is made available to us through our participation in two ARC LIEF grants with the University of Wollongong.

In March 2009 four members of the School's Advanced Materials research group (**Stewart Campbell, Hazar Salama, Glen Stewart and Jianli Wang**) travelled to Lucas Heights to attend a special AINSE *Symposium on Neutron Scattering and Magnetism*. The Symposium coincided with the publication of a special *Festschrift* issue of the *Journal of Physics: Condensed Matter* (Volume 21, Number 12, 25th March, 2009) to mark the occasion of the 70th birthday of Dr Trevor Hicks.

**Stewart Campbell, Glen Stewart and Jianli Wang** attended *ICAME2009*, the *International Conference on Applications of the Mössbauer Effect*, Vienna, 20-24 July 2009. **Glen Stewart** presented an invited talk entitled "Characterisation of the crystal field interaction in rare earth intermetallics using Mössbauer spectroscopy". In addition to attending several IBAME Board meetings, Stewart co-chaired a session on Solid State Physics at *ICAME2009*.

**Stewart Campbell and Jianli Wang** attended *ICM2009*, the *International Conference on Magnetism*, Karlsruhe, Germany, 26-31 July 2009. They presented a poster based on their refereed paper entitled "Magnetic properties of  $\text{Ho}_2\text{Fe}_{17-x}\text{Mn}_x$  - influence of Mn substitution". Stewart co-chaired a session on Magnetocaloric Effects at *ICM2009*. Stewart then travelled to the satellite conference *PNSXM2009* in Bonn, 2-5 August 2009, where together with co-worker Shane Kennedy, ANSTO, he presented a poster on neutron polarisation investigations of  $\text{ZnFe}_2\text{O}_4$  nanoparticles.

**Stewart Campbell and Jianli Wang** attended the Scoping Workshop on New Guides, Instruments and Sample-Environment Apparatus at OPAL, ANSTO, 27-28 August 2009.

## Service

**Stewart Campbell** - Australian representative on IBAME, the *International Board on Applications of the Mössbauer Effect*; Meeting Chair of the Instrument Advisory Team for Pelican, the new neutron polarization analysis, time-of-flight Instrument at OPAL, ANSTO.

### Wayne Hutchison

- Executive committee member of the ACT Branch Australian Institute of Physics since 2000.
- Member of the International Advisory Committee for the Conference on Hyperfine Interactions and is also a member of the 2010 Program Committee.

## Visitors

**Dr Jorge Fernandez Niello** from the National University of Buenos Aires, Argentina, visited **Laura Gladkis** and **Heiko Timmers**.

**Dr Wolf Dietrich Zeitz** from Hahn-Meitner Institut, Berlin was a Funded Visiting Fellow to PEMS, 1st September 2008-28th February 2009. He collaborated with **Heiko Timmers** and **Laura Gladkis** and other members of the Advanced Materials Research Group (in research using the Radioisotope Implanter Facility) as well as sharing his radioisotope expertise with others in PEMS.

**Heiko Timmers** hosted **Patrick Kessler**, from the University of Bonn from 14 April-10 May 2009.

**Wayne Hutchison** hosted **Phil Bruen** (a work experience student) 1-5 September 2009.

**Stewart Campbell and Jianli Wang** hosted several short-term visitors for seminar presentations and research discussions: 2008 - **Profs Horst Hahn and Michael Lowenhaupt** from Germany; **Dr Shane Kennedy, Frank Klose and Karl Whittle**, ANSTO; **Dr John Stride**, UNSW; **Drs Zbigniew Stachurski and Ying Chen**, the Australian National University; **Prof. Sean Cadogan** from Canada and **Dr Dennis Mather**, AINSE. Visitors so far in 2009 include: **Prof. Edie Sevick** and **Dr Genmiao Wang**, ANU; **Prof. Tom Johansen**, Norway; **Prof. Sean Cadogan**, Canada.