Institute for Superconducting & Electronic Materials

Annual Report 2009

University of Wollongong

Contents

Cover picture: Architects' perspective on current Australian Institute for Innovative Materials (left) and forthcoming Australian Institute for Innovative Materials – Processing & Devices (right)

Along with the $31M state-of-the-art AIIM facility, in May 2009 ISEM, IPRI and University of Wollongong secured another $50M through Education Investment Fund to build an extention – AIIM Processing & Devices. These two projects are ISEM's milestone achievements in 2007-2009.

ISEM Postgraduate Student Awards

Each year ISEM selects a number of outstanding students and in recognition of their research efforts, these students are presented with a Certificate to mark their achievements, together with a cash prize.

2009 Postgraduate Student Excellence Award Recipient

Anthony Wright

2009 Postgraduate Student Best Thesis Award Recipient

Yun Zhang

2009 Postgraduate Student Merit Award Recipients

Abbas Ranjbar

Chao Zhong

MD Mokhlesur Rahman

2009 Postgraduate Student Best Paper Award Recipients

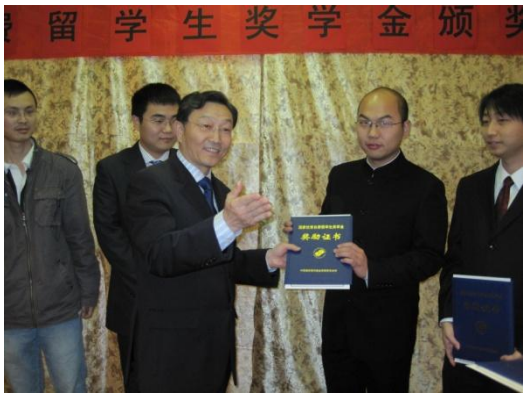
Krunal Radhanpura

Jianfeng Mao

2009 Chinese Government Scholarship Awards

The awards were presented by Mr. Shan Wu, the General Counsellor of Chinese General Consulate in Sydney.

Hao Liu and Shulei Chou



Peng Zhang

Director's Report

Prof. Shi Xue Dou
PhD, DSc, FTSE
ARC Australian Professorial Fellow

In 2009 Institute for Superconducting and Electronic Materials (ISEM) has been further settling in the newly built building – Australian Institute for Innovative Materials (AIIM). The $30M building consisting of world class facilities and state-of-the-art architecture is a highlight of the University of Wollongong effort to enhance its research potential, while introducing new environmental friendly solutions and concepts. Furthermore, ISEM was a part of a University of Wollongong application through Education Infrastructure Fund which saw another $46M allocated for construction of the extension to the AIIM facility, namely Australian Institute for Innovative Materials – Processing & Devices. The construction of the building is due to be commenced in 2010 and the grand opening of the building is planned in the middle of 2011. This new research and innovation facility will bridge the link between high class research and commercialization of research outcomes which are produced by two University of Wollongong flagship institutes ISEM and Intelligent Polymer Research Institute (IPRI). We are very proud of being a part of this great initiative by the University of Wollongong.

In year 2009 ISEM has continued to grow bigger and better in terms of research teams, quality and facilities. We kept on attracting high calibre personnel to maintain our targets in ARC fellows, full time researchers, postgraduate students, publications in higher impact journals and ARC funding. Yet again ISEM maintained its high class and excellent achievement in above mentioned categories: *(1)* the total ARC funding obtained in 2009 round exceeded $3.8 million; *(2)* we maintained our high publication rate counting more than 140 publications in various international journals, *(3)* we had 60 enrolled postgraduate students and we are confident that this number will increase in the years to come.

Major advancements in the study of superconductivity in various materials have been achieved. For MgB_2 superconductor, our investigations on the carbohydrate doping of the MgB_2 wires have set a new world record high critical current carrying capabilities, very promising for MRI and fault current limiter applications with collaboration with Geneva group and Hyper Tech using pressure rolling. In research of multilayered high temperature superconductors, YBCO, we have been able to develop a theoretical model, which explains critical current behaviour in such thin film multilayered structures and correlated these features to the domain distribution of the films. We have been actively working on newly discovered FeAs ($FeAsO_{0.89}F_{0.11}$). We showed that the upper critical field (H_{c2}) values can exceed 80-230T and superior performance of supercurrent density in fields, which further proves that these materials have tremendous potential for practical applications. In energy materials, numerous directions have produced significant and exciting results. For example, a new approach has been developed to rapidly synthesize nanostructured $LiMn_2O_4$ thin films by flame spray deposition (FSD) and *in situ* annealing. $LiMn_2O_4$ films exhibited good cyclability. Films that underwent sintering and crystal growth during *in situ* annealing developed more robust film structures on the current collector surface and exhibited better electrochemical performance. Further, with increasing interest in application of graphene for energy applications, a general strategy has been demonstrated to achieve optimum electrochemical performance by constructing 3D nanocomposite architecture with the combination of nanosize Sn particles and graphene nanosheets. The 3D nanoarchitecture gives the Sn/graphene nanocomposite electrode an enhanced electrochemical performance. Thus such composites can be successfully utilized to prepare anode and cathode materials for advanced energy storage and conversion devices. In electronic materials, we have further investigated highly promising multiferroic materials. Dielectric measurements showed that abnormal dielectric peaks in specific thin film microstructures were frequency dependent. The ac susceptibility measurement of the films showed that the peak position around 40 K is strongly dependent on frequency, indicating a glassy or relaxor type

behaviour. Therefore, relaxor type ferroelectric and magnetic $0.9Pb(Fe_{0.5}Nb_{0.5})O_3–0.1PbTiO_3$ is a magneto-electric relaxor. Furthermore, in physics we have vigorously researched physics and properties of graphene and other carbon based nanostructures. Our research also saw major achievements in the terahertz field, where we found that even such a well known process as peeling of adhesive tape, can generate terahertz radiation or enhancement of terahertz properties in GaAs and GaBiAs samples.

In 2009 our staff remained very active in their research, many of them have dedicated tremendous amount of time to setup new and maintain existing equipment. We are grateful to all of our staff members who have in any way contributed to this utterly important task. Dr. Joseph Horvat and Dr. Zaiping Guo have been promoted to Associate Professor and Senior Lecturer, respectively, which is a great recognition of this constant input into the research of applied superconductivity and electronic materials. In March 2009 ISEM has organized an International Workshop on Electronic Materials and their Application. The scope of the workshop was to gather world leaders in research and our industry partners to showcase progress in practical application of the researched materials in ISEM. The workshop attracted more than 20 high calibre speakers from around the globe and was a success. Later in the year ISEM was also co-organizer of an International Symposium on Renewable Energy Storage and Conversion Technologies. The workshop attracted many researchers working in field of energy materials to give their talks on the advances in this exciting research field. Throughout the year more than twenty internationally renowned researchers visited our institute. Our visitors, such as Prof. E. W. Collings from Ohio State University (USA), Prof. G. Ramanath from Rensselaer Polytechnic Institute (USA), Prof. R. Flukiger from University of Geneva (Switzerland), Dr. O. Mukhanov from Hypres (USA), Prof. J. Clarke from University of California (USA) and many others gave a number of interesting and exciting talks on various topics. We are grateful to these researchers for sharing their knowledge and experience with our staff and students.

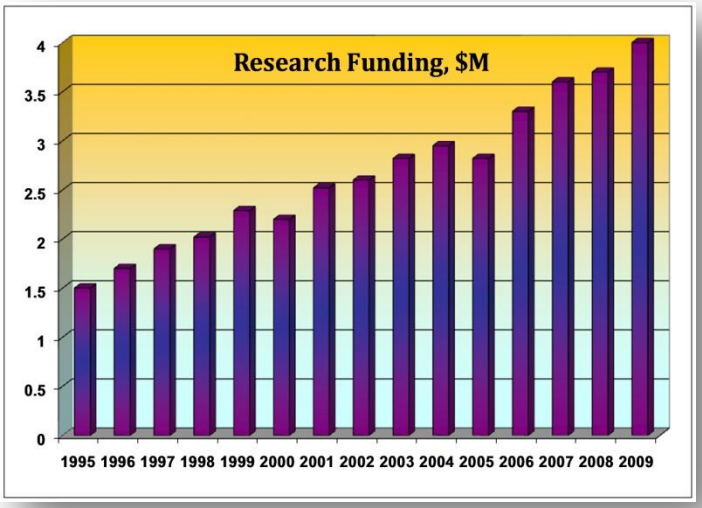
Yet again we have been excellent in the national competitive grant bids in the 2010 round with a total of $4,296,000 awarded. This includes, five Discovery Projects (Z. P. Guo (QEII); J. H. Kim/Y. Zhao/X. Zhu/Z.Q. Sun (APD); K. K. Konstantinov/H. K. Liu/A. Calka/D. Wexler; G. X. Wang/D. Wexler/A. Calka; X. L. Wang/G. Peleckis(APD)/D. P. Chen), two Linkage Projects (S. X. Dou/J. Horvat/X. Xu (APDI); J. Z. Wang/H. K. Liu/K. K. Konstantinov), Future Fellowship (Z. X. Cheng) and one Linkage Infrastructure Project as leading institute (S. X. Dou et al.).

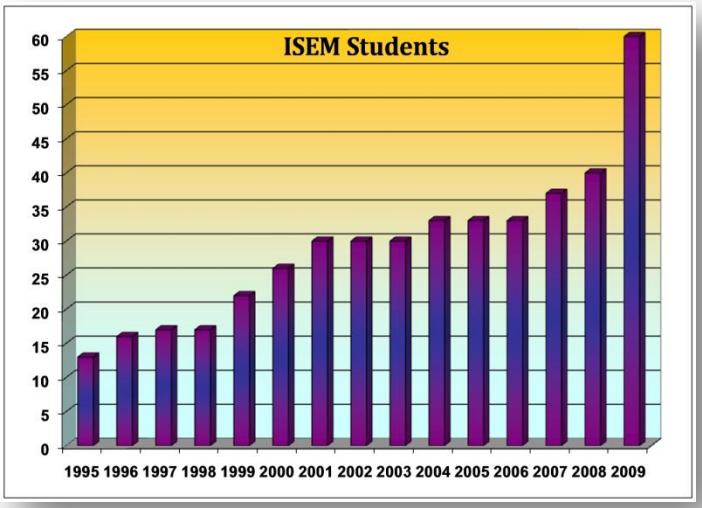
All our postgraduate students worked hard on their projects and achieved many significant results. The best achievers have been commended to receive annual Excellence, Merit and Best Paper Awards of ISEM and the Postgraduate Student Best Thesis Award of faculty. Shulei Chou has been awarded a very prestigious ECS (Electrochemical Society) summer fellowship hosted by the distinguished Professor Jeff Dohn (Dalhousie University, Canada). Three PhD candidates won the prestigious Chinese Government Scholarship Awards for self-funded students. We also want to welcome our new students and believe that excellent achievements of our current students will motivate them to achieve even better results in their scientific endeavours.

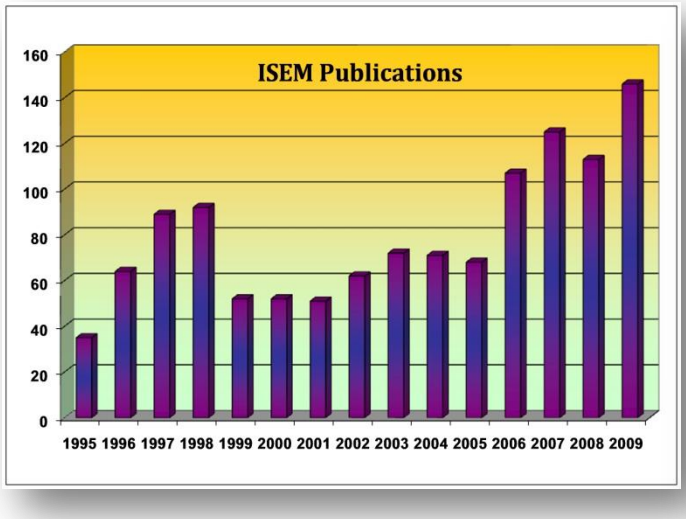
ISEM has benefited strongly from the relocation to the AIIM facility in terms of improvement of infrastructure. We have purchased a state-of-the-art single crystal growth facility, new x-ray diffraction equipment, TG/DTA system, 15T and 9T magnets for transport and characterization of samples. We improved our EBE/XPS system through National Cooperative Research Infrastructure Scheme (NCRIS). ISEM is expected to significantly increase its excellent infrastructure through $10M equipment fund available through the Education Investment Fund in the new AIIM P&D building. This funding will be allocated to purchase excellent pieces of equipment, especially for the brand new laboratory in the University of Wollongong – world class clean room laboratory, specifically designed to explore advanced manufacturing of microelectronic devices for a range of applications.

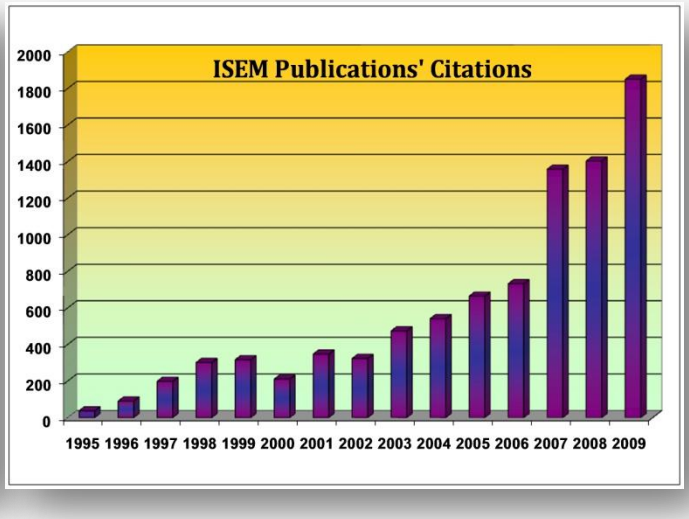
Shi Xue DOU
Director

ISEM Statistics









Management 2009

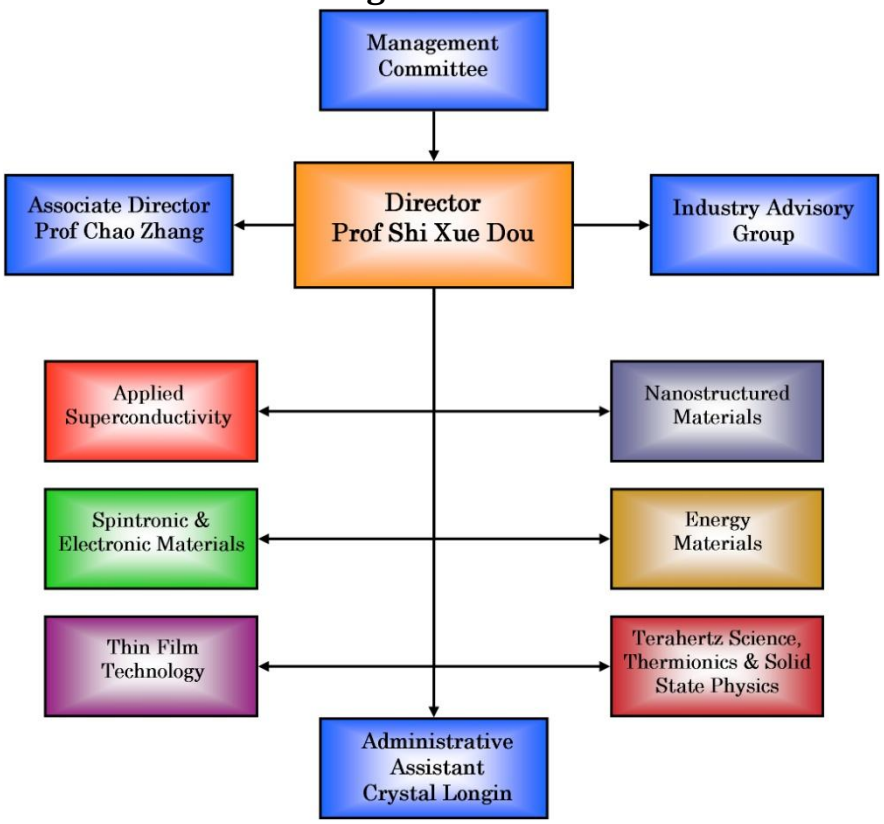
Management Committee

Chairperson:	Prof. Judy Raper	Deputy Vice Chancellor, UoW
	Prof. Shi Xue Dou	Director, ISEM
	Prof. Chris Cook	Dean, Faculty of Engineering, UoW
	Prof. Chao Zhang	Associate Director, ISEM
	Prof. Hua Kun Liu	Research Co-Coordinator, ISEM

Industry Advisory Group

Dr. F. Darmann	Managing Director	Zenergy Power Ltd.
Mr. J. F. Wu	Marketing Manager	DLG Battery Co Ltd, Shenzhen, P. R. China
Mr. M. Tomsic	Managing Director	Hyper Tech Research Ltd, Ohio, USA,
Dr. O. Mukhanov	Chief Technological Officer	Hypres Ltd, USA
Dr. X. F. Gao	General Manager	Lexel Batteries Co. Ltd, Shenzhen, P. R. China
Dr. S. Cooper	Chief Technological Officer	Mesaplexx Ltd, Brisbane, QLD, Australia
Mr. A. Kittel	Managing Director	Redarc Electronics, Adelaide, SA, Australia

ISEM Organisational Chart



Personnel

Director

- Prof. Shi Xue Dou *(Dipl, PhD, DSc, FTSE, Australian Professorial Fellow)*

Associate Director

- Prof. Chao Zhang *(BSc, PhD, MA, MPhil, FAIP)*

Senior Program Co-Coordinators

- A/Prof. Josip Horvat (BSc, PhD, FAIP)
- Dr. Kosta Konstantinov (BSc, MSc, PhD)
- Prof. Hua Kun Liu (Dipl. for PGS, APF)
- A/Prof. Alexey Pan (MSc, PhD, ARC ARF)
- A/Prof. Guoxiu Wang (MSc, PhD ARC QE-II Fellow)
- Prof. Xiaolin Wang (BSc, MSc, PhD, ARC QE-II Fellow)
- Prof. Chao Zhang (BSc, PhD, MA, MPhil, FAIP)

ARC Fellows

- Prof. Hua Kun Liu (Dipl. For PGS, Dipl. AQC, Australian Professorial Fellow)
- A/Prof. Alexey Pan (BSC, MSc, PhD, ARC Australian Research Fellow)
- Dr. Dongqi Shi (BSC, MSc, PhD, ARC Postdoctoral Fellow)
- A/Prof. Guoxiu Wang (BSc, MSc, PhD, ARC QE-II Fellow)
- Dr. Xiaolin Wang (BSc, MSc, PhD, ARC QE-II Fellow)
- Dr. Sihai Zhou (BSc, MSc, PhD, ARC Postdoctoral Fellow)
- Dr. Yue Zhao (MSc, PhD, ARC Postdoctoral Fellow)
- Dr. Xuebin Yu (BSc, MSc, PhD, ARC Postdoctoral Fellow)
- Dr. Dapeng Chen (BSc, MSc, PhD, ARC Postdoctoral Fellow)
- Dr. Zhenxiang Cheng (BSc, MSc, PhD, ARC Future Fellow)
- Dr. Xun Xu (BSc, MSc, PhD, ARC Postdoctoral Fellow)
- Prof. T. Johansen (ARC International Fellow)
- Dr. G. Hong (ARC International Fellow)
- Dr. Ivan Nevirkovets (PhD, NCRIS Fellow)

Research Staff

- Dr. Feng Gao (BSc, PhD)
- Dr. Tania Silver (BSc, PhD)
- Dr. Jung Ho Kim (BSc, PhD)
- Dr. Rong Zeng (BSc, MSc, PhD)
- Dr. Germanas Peleckis (PhD)
- Dr. Olga Shcherbakova (PhD)
- Prof. Xiaoping Shen
- Dr. Chunchang Wang
- Dr. Jiazhao Wang (BSc, MSc, PhD)
- Dr. Shouyu Wang
- Dr. Yueping Yao
- Dr. Xuebin Zhu

Faculty Staff

- Prof. Chris Cook (BSc, PhD, FIEAust)
- Dr. Carey Freeth (MSc, PhD, MAIP)
- Prof. Roger Lewis (BSc (Hons), PhD, FAIP, FRMS)
- Dr. David Martin (MSc, PhD, MAIP)
- A/Prof. Rodney Vickers (MSc, PhD, MAIP)
- Dr. Zaiping Guo (BSc, MSc, PhD)

Visiting Staff

- Prof. Edward Collings (Ohio State University)
- Dr. Shi Zhong (Delong Energy Technology, China)
- Dr. Shane Kennedy
- Dr. Gustavo Alvarez
- Dr. Hai Bo Lu
- Dr. Jieqiang Wang
- Dr. Xianlong Wang
- Dr. Xibin Xu
- Dr. Yunlong Xu
- Dr. Zunxian Yang
- Dr. Xianjun Zhu

Technical Staff

- Mr. Ron Kinnell
- Mr. Robert Morgan
- Mr. Darren Attard

Administration Assistant

- Ms. Crystal Longin

Honorary Fellows

- Dr. Scott Needham

Postgraduate Students

Current

PhD	Thesis Title	Supervisors
Mr. Mislav Mustapic	Enhancement of MgB_2 superconductor by magnetic nanoparticle doping	A/Prof. J. Horvat Prof. Shi Xue Dou
Mr. Dieter Beaven	FPGA architecture for numerical computations	Prof. John Fulcher, Prof. Chao Zhang
Mrs. Fargol Bijarbooneh	Nanowires in arrays based nanostructures	Dr. Yue Zhao, Dr. Jung Ho Kim
Mr. Colin Bleasdale	Electromagnetic properties of superconducting films and multilayers	Prof. Chao Zhang, A/Prof. Alexey Pan
Mr. Shulei Chou	Nanostructured / composite materials for rechargeable Li-ion battery and supercapacitor	Prof. Hua Kun Liu, Prof. Shi Xue Dou, Dr. Jiazhao Wang
Mr. Jyotish Debnath	Nanostructure control of MgB_2 by chemical doping	Prof. Shi Xue Dou, Dr. Jung Ho Kim, Dr. Rong Zeng
Mr. Guodong Du	Performance improvement of cathode materials for Li-ion battery	Dr. Zaiping Guo, Prof. Hua Kun Liu
Mr. Yi Du	Diluted magnetic semiconductors (DMS's)	Prof. Xiaolin Wang, Dr. Zhenxiang Cheng
Mr. Mohd Faiz Hassan	Nanostructured materials for lithium ion battery	Prof. Hua Kun Liu, Dr. Zaiping Guo
Mrs. Nurul Idris	Nanomaterials for lithium rechargeable batteries	Prof. Hua Kun Liu, Dr. Jiazhao Wang
Mr. Mohammad Ismail	Hydrogen storage materials	Prof. Shi Xue Dou, Dr. Yue Zhao, Dr. Xuebin Yu
Ms. Priyanka Jood	Oxide thermoelectric materials for high temperature power generation	Dr. Germanas Peleckis, Prof. Xiaolin Wang
Mr. Philip Lavers	Electronic structure of perovskite and related materials	Prof. Shi Xue Dou
Mrs Lin Lu	Electrolytes for rechargeable batteries	Dr. Jia Zhao Wang, Prof. Hua Kun Liu
Mr. Qi Li	Research on superconducting films and buffer layers for electronic applications	Prof. Shi Xue Dou, Dr. Dongqi Shi
Mr. Wenxian Li	Carbohydrate doping effect on the superconductivities and microstructure of MgB_2 superconductor	Prof. Shi Xue Dou, Dr. Rong Zeng
Mr. Hao Liu	Nanostructured materials for lithium ion batteries	Dr. Guoxiu Wang, Prof. Chao Zhang
Mr. Minoru Maeda	Critical current of MgB_2	Prof. Shi Xue Dou, Dr Yue Zhao

PhD	Thesis Title	Supervisors
Mr. Jianfeng Mao	Study on hydrogen storage behaviour of $LiBH_4$	Dr. Zaiping Guo, Prof. Hua Kun Liu
Miss. Rashmi Nigam	Study of magnetic behaviour of Ru-based superconducting ferromagnets	A/Prof. Alexey Pan, Prof. Shi Xue Dou
Mr. Jinsoo Park	Synthesis of nanowires and their application as nanosensors for chemical detection	Dr. Guoxiu Wang, Prof. Hua Kun Liu
Mr. Chung Kiak Poh	Spintronic materials	Dr. Zaiping Guo, Prof. Hua Kun Liu
Mr. Serhiy Pysarenko	HTS multi-layers thin films fabrication	A/Prof. Alexey Pan, Prof. Shi Xue Dou
Mr. MD Mokhlesur Rahman	Nanostructured active materials for lithium-ion batteries	Prof. Hua Kun Liu, Dr. Jiazhao Wang
Mr. Abbas Ranjbar	Effect of catalysts on hydrogen storage properties of MgH_2	Prof. Hua Kun Liu, Dr. Zaiping Guo
Mr. Ali Ranjbartoreh	A study of hydrogen storage and hydrogen-fed PEM fuel cells	A/Prof. Guoxiu Wang
Mrs. Precious Shamba	High T_c superconductivity	Prof. Shi Xue Dou Dr. Rong Zeng
Mr. Andrey Shcherbakov	Development of MgB_2 wires with aluminum as a stabilizer	Prof. Shi Xue Dou, A/Prof. Josip Horvat
Miss. Ying Wang	Research on $LiFePO_4$ preparation and application	Dr. Guoxiu Wang
Mr. Brad Winton	Magnetoresistive effect in Bi-2212	Prof. Shi Xue Dou, Dr. Micheal Ionescu
Mr. Anthony Wright	Charge and energy transport in carbon nanotubes	Prof. Chao Zhang, A/Prof. Guoxiu Wang
Ms. Huimin Wu	New catalyst materials for hydrogen fed fuel-cells	Dr. Guoxiu Wang Prof Hua Kun Liu
Mr. Peng Zhang	Thin film electrodes for lithium ion battery	Dr. Zaiping Guo, Prof. Hua Kun Liu
Miss. Lin Wang	YBCO coated conductor through chemical solution deposition	Prof. Shi Xue Dou, Dr. Dongqi Shi

Master's	Thesis Title	Supervisors
Mr. Bei Wang	Nanostructured materials for advanced supercapacitors	Dr. Guoxiu Wang
Mr. Chao Zhong	Nano electrode materials for energy storage	Prof. Hua Kun Liu, Dr. Jiazhao Wang

Completions

PhD Graduates

PhD Name	Thesis Title	Awarded	Position	Appointed
Q. Yao	Study of newly discovered two dimensional cobalt based perovskite compounds doped with various rare earth elements	2009	Research Associate, ISEM, University of Wollongong	2009
Y. Zhang	Improvement of critical current density in MgB_2 by optimizing process parameters and chemical doping	2009	Research Associate, ISEM, University of Wollongong	2009
X. Xu	Effect of starting boron powder on the superconducting properties of MgB_2	2009	ARC APDI Fellow, ISEM, University of Wollongong	2010
S. Y. Chew	Advanced materials for electrodes and electrolyte in rechargeable lithium ion batteries	2009		
D. P. Chen	Crystal growth, magnetism, transport and superconductivity of two dimensional sodium cobalt oxide single crystals	2009	ARC APD Fellow, ISEM, University of Wollongong	2009
M. M. Farhoudi	Studies of structures, transport and magnetic properties of doped novel three dimensional perovskite compounds	2009		
Y. P. Yao	A study of electro materials for lithium-ion batteries	2008	Part Time Associate Fellow, ISEM, University of Wollongong	2008
Z. W. Zhao	The liquid-phase synthesis and electrochemical application of novel inorganic nanocomposites	2008	Innovation Management Department, Bayer Technology and Engineering Co., Ltd., Shanghai, China	2008
O. Shcherbakova	Development of $MgB_{2-x}C_x$ superconductors and understanding their electromagnetic behaviour	2008	Part Time Associate Fellow, ISEM, University of Wollongong	2008
M. S. Park	Synthesis and characterization of nanostructured electrode materials for rechargeable lithium ion batteries	2008	Energy Group, Emerging Centre, Samsung Advanced Institute of Technology, South Korea	2008
M. S. A. Hossain	Study of superconducting and electromagnetic properties of un-doped and organic compound doped MgB_2 conductors	2008	Applied Superconductivity Group, University of Geneva, Switzerland	2008

PhD Name	Thesis Title	Awarded	Position	Appointed
S.H. Ng	Nanostructured materials for electrodes in lithium-ion batteries	2008	Post doctorate Fellow, Electrochemistry Laboratory, Paul Scherrer Institute, Switzerland	2008
			Technical Customer Support Manager, Asia Pacific, Changzhou Timcal Graphite Corp. Ltd, Shanghai, China	2009
Z. G. Huang	Effects of compositions and mechanical milling modes on hydrogen storage properties	2008	Research Fellow, Department of Materials Science and Engineering, OHIO State University, USA	2008
S. A. Needham	Development of advanced electrode materials for lithium-ion batteries	2007	Commercialization Manager, University of Wollongong	2007
			Commercialization Manager, Intven Ltd.	2009
G. Peleckis	Studies on diluted oxide magnetic semiconductors for spin electronic applications	2007	Research Fellow, ISEM, University of Wollongong	2007
			ARC APD Fellow, ISEM, University of Wollongong	2010
M. Roussel	Magneto-optical imaging in superconductors	2007	Director of the Capacity Building Department, BlueEnergy, Nicaragua	2008
L. Yuan	Investigation of anode materials for lithium-ion batteries	2007	CEO	2006
M. O'Dwyer	Solid-state refrigeration and power generation using semiconductor nanostructures	2007	Trading Analytics, Energy Australia	2007
Y. Chen	Investigation on advanced active materials for lithium-ion batteries	2006	General Manager, DLG Battery Shanghai CO.LTD	2006
S. Bewlay	Investigation on Li-Co-Ni system for lithium ion batteries	2006	Patent Officer, Canberra	2006
A. Li	A study of the fabrication and characterization of high temperature superconductor $YBa_2Cu_3O_7$ thin films	2006	Associate Research Fellow, ISEM, University of Wollongong	2006
S. H. Pilehrood	Electronic properties of semiconductor nanostructures under intense terahertz radiation	2006		
W. K. Yeoh	Control of nanostructure for enhancing superconductor performance through chemical doping	2006	Research Fellow, Cambridge University, U.K.	2007

PhD Name	Thesis Title	Awarded	Position	Appointed
Y. Zhao	Fabrication and characterization of superconducting PLD MgB_2 thin films	2006	APD Fellow ISEM, University of Wollongong Lecturer, University of Wollongong	2006 2008
S. Keshavarzi	Investigation of vortex dynamics of $(Tl,Pb)(Sr,Ba)_2Ca_2Cu_3O_y$ and an alternative method for determination of the lock-in angle in twinned superconductors	2005	Lecturer, Shahrekord University, Iran	2005
F. Gao	Studies on the synthesis, characterization and properties of colossal magnetoresistive (CMR) materials	2004	Research Fellow, ISEM, University of Wollongong	2004
M. Lindsay	Data analysis and anode materials for lithium ion batteries	2004	Postdoctoral Research Fellow, University of New South Wales Research Staff , ANSTO	2004 2006
B. Lough	Investigations into thermionic cooling for domestic refrigeration	2004	Quantitative Analyst, ABN AMRO, UK	2005
D. Milliken	Uranium doping of silver sheathed bismuth-strontium-calcium-copper-oxide superconducting tapes for increased critical current density through enhanced flux pinning	2004	Knowledge Transfer Partnership Associate, University of Leeds and AVX Ltd	2005
S. Soltanian	Development of superconducting magnesium diboride conductors	2004	Pro-Vice Chancellor, Kurdistan University, Iran	2005
C. Wang	Cathodic materials for nickel-metal hydride batteries	2004	Research Fellow, IPRI, University of Wollongong	2004
S. H. Zhou	Processing and characterization of MgB_2 superconductors	2004	APD Fellow, ISEM, University of Wollongong	2005
Z. P. Guo	Investigation on cathode materials for lithium-ion batteries	2003	APD Fellow, ISEM, University of Wollongong Lecturer, University of Wollongong	2003 2007
J. McKinnon	The fundamental mechanisms involved in the production of thin films by Pulsed laser	2003	Teacher, New South Wales Education Department	2003
D. Marinaro	A study into the effects of fission-fragment damage on activation Energies in Ag/Bi2223 tapes	2003	Scientist, DSTO Melbourne	2003

PhD Name	Thesis Title	Awarded	Position	Appointed
D. Q. Shi	Buffer layers for YBCO superconducting films on single crystal YSZ substrates and cubic texture Ni substrates	2003	Research Fellow, Korean Electrical Technology Institute, Korea	2002
			Research Fellow, ISEM, University of Wollongong	2004
			APD Fellow, ISEM, University of Wollongong	2007
J. Wang	Development of a novel plate making processing technique for Manufacturing valve-regulated lead-acid batteries	2003	Research Fellow, IPRI, University of Wollongong	2003
			APD Fellow, ISEM, University of Wollongong	2004
			Research Fellow, ISEM	2007
R. Baker	Zeeman and piezo-spectroscopy of antimony and aluminium in germanium	2001	Professional Officer, University of Wollongong	2003
X. K. Fu	Fabrication and characterization of Bi-2223 current lead	2002	Research Fellow, Texas A&M University, USA	2002
			Research Fellow, University of Waterloo, Canada	2005
K. Uprety	Magnetic hysteresis and relaxation in Bi2212 single crystals doped with iron and lead	2002	Research Fellow, Argonne National Lab, USA	2002
F. Darmann	AC Loss in high temperature superconductor	2001	Chief Engineer, Zenergy Power Ltd.	2004
G. X. Wang	Investigation on electrode materials for lithium-ion batteries	2001	APD Fellow, ISEM, University of Wollongong	2001
			ARC QEII Fellow, ISEM, University of Wollongong	2006
			Associate Professor, ISEM, University of Wollongong	
J. P. Chelliah	Optical spectroscopy of semiconductors	2000		
L. Sun	Amorphous and nanocrystalline hydrogen storage alloy materials for nickel-metal hydride batteries	2000	Research Associate, Hydro-Quebec Research Institute, Canada	2000
			Research Fellow, University Sherbrooke, Canada	2002

PhD Name	Thesis Title	Awarded	Position	Appointed
X. L. Wang	Spiral growth, flux pinning and peak effect in doped and pure Bi-2212 HTS single crystal	2000	Research Fellow, ISEM, University of Wollongong	2000
			ARC APD Fellow, ISEM, University of Wollongong	2002
			ARC QEII Fellow, ISEM, University of Wollongong	2005
			Associate Professor	2006
			Professor	2008
R. Zeng	Processing and characterization of Bi-2223/Ag superconducting tapes	2000	Research Fellow, ISEM, University of Wollongong	2000
J. Chen	High energy storage material for rechargeable nickel-metal hydride batteries	1999	NEDO Fellow, Osaka National Research Institute	1999
			Professor, Nankai University, China	2003
T. Silver	Near band-edge optical properties of MBE GaAs and related layered structures	1999	Research Fellow, ISEM, University of Wollongong	2000
G. Takacs	Spectroscopy of the effect of strains and magnetic field on shallow acceptor levels in germanium	1999	Lab Manager, University of Wollongong	1999
N. Cui	Magnesium based hydrogen storage alloy anode materials for Ni-MH secondary batteries	1998	Research Fellow, Alberta University, Canada	1997
			Electrochemist, Energizer Co, USA	2000
R. J. Heron	Far-infrared studies of semiconductors in large magnetic fields	1998	Postdoctoral Fellow, SUNY, Buffalo, USA	1997
			Research Fellow, Janis Research Company Inc., USA	2000
M. Ionescu	Growth and characterization of Bi-2212 crystals and improvement of Bi-2212/Ag superconducting tapes	1998	Assistant Director, ISEM, University of Wollongong	1997
			Senior Research Scientist, ANSTO	2004
J. X. Jin	$(Bi,Pb)_2Sr_2Ca_2Cu_3O_{10+x}$/Ag high T_c superconductors and their applications in an electrical fault current limiter and an electronic high voltage generator	1998	Research Fellow, ISEM, University of Wollongong	1997
			ARC, APD Fellow, ISEM, University of Wollongong	2000
			Professor, University of Electronic Engineering	2003

PhD Name	Thesis Title	Awarded	Position	Appointed
M. Lerch	Optical & electrical studies of resonant tunnelling heterostructure	1998	Lecturer, School of Engineering Physics, University of Wollongong	2006
S. Stewart	Thermodynamic and dielectric properties in modulated two-dimensional electronic systems	1998	ARC APD Fellow	1998
			Teacher	1999
			Associate Professor	2002
W. G. Wang	Fabrication and improvement of silver sheathed $(Bi,Pb)_2Sr_2Ca_2Cu_3O_{10}$ tapes By powder-in-tube technique	1998	R&D Manager, Nordic Superconductor Tech. Denmark	1997
			Associate Director, Ningbo Materials Institute, Chinese Academy	2007
B. Zeimetz	High temperature superconducting tapes & current leads	1998	Research Fellow, Cambridge Univ., U.K.	1999
S. Zhong	Investigation on lead-calcium-tin-aluminium grid alloys for valve-regulated lead-acid batteries	1998	ARC Postdoctoral Fellow, ISEM, University of Wollongong	1997
			CEO, Leadcel Dynamic Energy Ltd, P.R. China	2002
			CEO, Guangzhou Delong Energy Tech Ltd.	2003
B. L. Luan	Investigations on Ti_2Ni hydrogen storage alloy electrode for Rechargeable nickel-metal hydride batteries	1997	NRC Fellow, National Res. Council of Canada	1997
			Group Leader, Shape Transfer Process Integrated Manufacturing Technologies Institute, NRC, Canada	1999
N. Vo	Design and characterization of HTS coils	1997	Research Fellow, Los Alamos Nat. Lab, USA	1999
			Research Staff, Intermagnetics General Co., USA	1998
A. Warner	A spectroscopic study of acceptors in germanium	1997	Consultant, Computer Industry	1999
J. M. Xu	Phase formation and transformation in the R-Fe-T system (R=Nd, Gd, Tb, Dy, Er, Ho, T and Lu, T=Si, Ti & Zr	1997	Research Fellow, St. George Bank, Australia	1998

PhD Name	Thesis Title	Awarded	Position	Appointed
M. Yavus	Powder processing of Bi-Pb-Sr-Ca-Cu-O superconducting materials	1997	Ass. Professor, Texas A&M University, Texas USA	2000
			Ass. Research Professor, Tohoku University, Sendai, Japan	1997
			Ass. Professor, University of Waterloo, Canada	2004
Q. Y. Hu	Fabrication and enhancement of critical currents of silver sheathed $Bi,Pb_2Sr_2Ca_3Cu_3O_{10}$ tapes	1996	Research Fellow, Florida State University, USA	1997
			Research Scientist, Argonne National Lab., USA	1999
			Senior Engineer, Lucent, USA	2001
J. Yau	Ag/Bi-2223 tape processing and mechanical properties	1994	Assistant Professor, City Polytechnic University	2000
J. A. Xia	Characterization of melt-texture of YBCO HTS	1994	Research Fellow, Solar Cell Ltd	1995
Y. C. Guo	Investigation of silver-clad $(Bi,Pb)_2Sr_2Ca_2Cu_3O_{10-x}$ superconducting tapes	1994	STA Fellow, National Research Institute Of Metals, Japan	1997
			ARC Postdoctoral Fellow, ISEM, University of Wollongong	1998
			Senior IT Specialist, ITS, University of Wollongong	2002
A. Bourdillion	Microstructure, phase characterization and texture processing of HTS	1992	Senior Engineer, Hewlett Packard, Singapore	1993
			Hewlett Packard, USA	2000
M. Apperley	The fabrication of high T_c superconductor wire	1992	Chief Technologist, Australian Superconductors	1993
			Business Development Manager, University of Sydney	2004

Master Course Graduates

Masters Name	Thesis Title	Awarded	Position	Appointed
L. Lu	Enhancement of connectivity and flux pinning in MgB_2 superconducting bulk and wires	2009	PhD Candidate, ISEM	2009

Masters Name	Thesis Title	Awarded	Position	Appointed
Y. S. Wu	Fabrication of in-situ MgB_2 thin films on Al_2O_3 substrate using off-axis PLD technique	2007	PhD Candidate, ANU	2008
Z. J. Lao	New materials for supercapacitors	2006	Engineer, Sydney	2007
B. Winton	A study of the magnetoresistance effect in Bi-2212 for the purposes of utilisation in magnetic field sensors	2005	PhD Candidate, ISEM, University of Wollongong	2005
Q. Yao	MgB_2 thin films	2005	PhD Candidate, ISEM, University of Wollongong	2005
P. Lavers	The mobility of large anions in crystals with the fluorite Structure	2004	PhD Candidate, ISEM, University of Wollongong	2004
J. Yao	Carbon based anode materials for lithium-ion batteries	2004	PhD Candidate, ISEM, University of Wollongong	2004
Z. W. Zhao	Nano-oxides fabricated in-situ by spray pyrolysis technique as anode materials for lithium secondary batteries	2004	PhD Candidate, ISEM, University of Wollongong	2004
K. Ishida	Landau spectra of ZnH and neutral Zn in germanium	2004		
S. Lee	Multilayer thermionic cooling in GaAs-$Al_xGa_{1-x}As$ heterostructures	2003		
Z. Zhang	The comparative research on the Ag-alloy sheathed Bi-2223 tapes	2003	Senior Staff, China-URC Ltd, Shanghai. PR China	2003
A. Li	Fabrication and characterization of novel substrates and superconducting thick films	2002	PhD Candidate, ISEM, University of Wollongong	2002
M. Farhoudi	AC loss in Ag/Bi-2223 tape in AC field	2002	PhD Candidate, ISEM, University of Wollongong	2003
M. Ling	Mechanism of outgrowth in multifilament Bi-2223 tape	2001		
E. Sotirova	Investigation of colossal magnetoresistance materials	2001	Learning Centre Employee, Communications Assistant, Star CD Pty Ltd	2002
K. Uprety	Vortex properties of Bi-HTS	1999	PhD Candidate, ISEM, University of Wollongong Research Fellow, Argonne National Lab., USA	2000 2003

Masters Name	Thesis Title	Awarded	Position	Appointed
J. Z. Wang	Investigations on anode materials for rechargeable lithium-ion batteries	1999	PhD Candidate, ISEM, University of Wollongong	2000
			Research Fellow, ISEM, University of Wollongong	2003
F. Chen	The influence of selenium on lead-calcium-tin-aluminium	1998	PhD Candidate, University of Sydney, Australia	1999
G. Yang	Effect of element substitution on superconductivity	1997	Research Fellow, University of Melbourne	2000
N. Zahir	A new method for production and study of electrical properties of carbon foam	1996	PhD Candidate, Queensland University	1997
J. X. Jin	$(Bi,Pb)_2Sr_2Ca_2Cu_3O_{10+x}$/Ag high T_c superconductors and their applications in an electrical fault current limiter and an electronic high voltage generator	1994	Research Fellow, ISEM, University of Wollongong	1997
			ARC, PDF, ISEM, University of Wollongong	2000

National and International Links

Australia

Australian Nuclear Science & Technology Organisation (ANSTO)
Australian National University
CSIRO Division of Applied Physics
Curtin University of Technology
James Cook University
Macquarie University
Monash University
University of Melbourne
University of New South Wales
University of Queensland
University of Sydney
University of Technology, Sydney
University of Western Australia
University of Western Sydney
Swinburne University of Technology

International

Austria
Atomic Institute of Austrian Universities, Vienna
L. Bolzmann Institute of Physics

Canada
'Ecole Polytechnique de Montreal
University of Alberta

Croatia
University of Zagreb

Germany
Max-Planck-Institut fur Metalloforschung

India
National Physical Laboratory

Japan
National Institute of Advanced Industrial Science and Technology (AIST)
National Institute of Materials Science
Osaka National Research Institute
Tokai University
Yamagata University

New Zealand
University of Auckland
Industrial Research Lab

Peoples Republic of China
Beijing University of Science and Technology
Harbin University
Hubei University
Institute for Microsystems and Information Technology
Institute of Electrical Technology
Institute of Non-ferrous Metals
Nankai University
Nanjing University
Northeastern University
Shanghai Jiao Tong University
Shanghai University
Tianjin University

Russia
Institute of General Physics

Singapore
National University
Nanyang University of Technology

South Korea
Andong National University
Korea Advanced Institute of Science & Technology
Korea Aerospace Research Institute (KARI)
Korea Institute of Materials Science (KIMS)
Korea Electrotechnology Research Institute (KERI)

Switzerland
University of Geneva
Paul Scherrer Institute

Ukraine
Donetsk Physico-Technical Institute
Institute for Metal Physics

United Kingdom
Imperial College
Oxford University
Southhampton University
University of Cambridge

United States of America
Ames Lab, Iowa State University
Argonne National Laboratory
Brookhaven National Laboratory
Houston University
Los Alamos Laboratory
National Institute of Standard Technology
New York Polytechnic University
Ohio State University
University of Wisconsin
Rensselaer Polytechnic Institute

Progress Reports for Projects funded by the Australian Research Council

ARC Centre of Excellence Research

ARC Centre of Excellence

All solid-state lithium rechargeable batteries *(within the ARC Centre of Excellence for Electromaterials Science, Director: G. G. Wallace)*

Funded:	2005 2006 2007 2008 2009 2010
Project ID:	CE0561616
Chief Investigator:	H. K. Liu
Research Fellow:	J. Z. Wang
Associate investigators:	Z. P. Guo, K. K. Konstantinov, G. X. Wang, J. Y. Lee, J. H. Ahn
PhD students:	S. L. Chou, MD. M. Rahman, N. Idris, C. Zhong, L. Neorochim

Progress made in 2009

A comparative study of conductive, free-standing, binder-free flexible films made from three different types of commercial carbon nanotubes (CNTs), i.e., single-wall, double-wall, and multi-wall was carried out. The conductive CNT films were prepared by adding the CNTs to the starting dispersion of carbon black and Triton X-100, followed by a vacuum filtration technique. These films have been characterized as model free-standing, binder-free electrodes for flexible lithium-ion batteries. Our experiments revealed that films based on multi-wall CNTs (MWCNTs) are much better than single-wall and double-wall CNTs films in terms of their electrochemical performance. The flexible MWCNT electrodes show stable cycling behaviour and allow up to a 10 C-rate.

Self-supported free-standing polypyrrole films have been prepared using the electrochemical polymerization method. The results show that the free-standing films can be directly used as electrode materials for batteries without the need for metal substrate support. The flexible cathode materials can be combined with a flexible carbon nanotube paper anode and a polymer electrolyte to make flexible and bendable rechargeable batteries.

Vanadium pentoxide (V_2O_5) nanoparticles (30–60 nm) were made by a one-step and scalable flame spray pyrolysis (FSP) process. Optimization of the FSP processing conditions (precursor concentration and injection rate) enhanced the electrochemical performance of these nanoparticles. Increasing the cut-off potential for discharging from 1.5 to 2.5 V vs. Li/Li^+ improved the cycle life of these V_2O_5 nanoparticles. Particles with the lowest specific surface area (~32 m2/g) and highest phase purity (up to 98 wt%) showed excellent cyclability between 2.5 and 4.0 V vs. Li/Li^+, retaining a specific charge of 110 mAh/g beyond 100 cycles at a specific current of 100 mA/g, and also superior specific charge of 100 mAh/g at specific current up to 20C rate (or 2000 mA/g).

A new approach has been developed to rapidly synthesize nanostructured $LiMn_2O_4$ thin films by flame spray deposition (FSD) and *in situ* annealing. A precursor solution of lithium acetylacetonate and manganese acetylacetonate in an organic solution was supplied through a flame spray pyrolysis (FSP) reactor. The liquid solution spray was ignited and stabilized by a premixed methane/oxygen flame ring surrounding the FSP nozzle. Thus, $LiMn_2O_4$ nanoparticles were formed by combustion and deposited onto a current collector followed by *in situ* annealing. Two different types of current collectors, i.e. stainless steel and aluminum coated with carbon-based primer were tested. The prepared thin films were characterized by X-ray diffraction and field-emission scanning electron microscopy. The electrochemical properties of the thin films were evaluated by cyclic voltammetry and galvanostatic cycling. The $LiMn_2O_4$ films exhibited good cyclability. Films that underwent sintering and crystal growth during *in situ* annealing developed more robust film structures on the current collector surface and exhibited better electrochemical performance than poorly adhered films.

The effects of zinc oxide doping on $LiFePO_4$ have been studied by X-ray diffraction (XRD), scanning electron microscopy (SEM), electrochemical impedance spectroscopy (EIS), cyclic voltammetry (CV), and galvanostatic measurements. The XRD patterns demonstrate that the samples have the phase of $LiFePO_4$ with an ordered olivine structure indexed to the orthorhombic *Pmna* space group. Also, XRD patterns show with the presence of $LiZnPO_4$ phase for zinc oxide doped samples. The EIS results showed that the conductivity is enhanced by zinc oxide doping. The 2.5% ZnO-doped $LiFePO_4$ demonstrated higher conductivity than the 1.5% ZnO and 5% ZnO-doped $LiFePO_4$ or the un-doped sample. The CV curves show that 2.5% ZnO-doped $LiFePO_4$ has higher electrochemical reactivity for lithium insertion and extraction than the un-doped material. The mean redox potential is $E1/2 = 3.45V$ *vs.* Li+/Li. The first discharge curve of the 2.5% ZnO-doped $LiFePO_4$ shows a mainly flat voltage plateau over the 3.45–3.5V range, indicating the lithium extraction and insertion reactions between $LiFePO_4$ and $FePO_4$. A specific discharge capacity of about 177mAh/g was achieved, with little decrease during cycling.

Publications

1. A. Y. Shenouda and H. K. Liu, "Studies on electrochemical behaviour of zinc-doped $LiFePO_4$ for lithium battery positive electrode", *Journal of Alloys and Compounds* **477**, 498 (2009).
2. S. Y. Chew, T. J. Patey, O. Waser, S. H. Ng, R. Büchel, A. Tricoli, F. Krumeich, J. Wang, H. K. Liu, S. E. Pratsinis, and P. Novák, "Thin nanostructured $LiMn_2O_4$ films by flame spray deposition and *in situ* annealing method", *Journal of Power Sources* **189(1)**, 449 (2009).
3. S. H. Ng, T. J. Patey, R. Buchel, F. Krumeich, J. Z. Wang, H. K. Liu, S. E. Pratsinis, and P. Novák, "Flame spray-pyrolyzed vanadium oxide nanoparticles for lithium battery cathodes", *Physical Chemistry Chemical Physics*, **11**, 3748 (2009).
4. K. Kim, S. Ahn, H. S. Kim, and H. K. Liu, "Electrochemical and thermal properties of 2,4,6-tris(trifluoromethyl)-1,3,5-triazine as a flame retardant additive in Li-ion batteries", *Electrochimica Acta* **54**, 2259 (2009).
5. S. Y. Chew, S. H. Ng, J. Wang, P. Novák, F. Krumeich, S. L. Chou, J. Chen, and H. K. Liu, "Flexible free-standing carbon nanotube films for model lithium-ion batteries", *Carbon* **47**, 2976 (2009).
6. J. Z. Wang, S. L. Chou, H. Liu, G. X. Wang, C. Zhong, S. Y. Chew, and H. K., "Highly flexible and bendable free-standing thin film polymer for battery application", *Materials Letters* **63**, 2352 (2009).
7. J. Chen, J. Wang, A. I. Minett, Y. Liu, Y. C. M. Lynam, H. K. Liu, and G. G. Wallace, "Carbon nanotube network modified carbon fibre paper for Li ion batteries", *Energy and Environmental Science* **2**, 393 (2009).
8. S. L. Chou, J. Z. Wang, H. K. Liu, and S. X. Dou, "SnO_2 meso-scale tubes: one-step, room temperature electrodeposition synthesis and kinetic investigation", Electrochemistry Communications **11**, 242 (2009).
9. S. L. Chou, J. Z. Wang, C. Zhong, M. M. Rahman, H. K. Liu, and S. X. Dou, "A facile route to carbon-coated SnO_2 nanoparticles combined with a new binder for enhanced cyclability of Li-ion rechargeable batteries", Electrochimica Acta **54**, 7519 (2009).
10. S. H. Ng, S. Y. Chew, J. Z. Wang, J. Chen, S. X. Dou, and H. K. Liu, "Foam-like, microstructural SnO_2–carbon composite thin films synthesized *via* a polyol-assisted thermal decomposition method", *Dalton Transactions* **4**, 723 (2009).
11. M. M. Rahman, J. Z. Wang, X. L. Deng, Y. Li, and H. K. Liu, "Hydrothermal synthesis of nanostructured Co_3O_4 materials under pulsed magnetic field and with an aging technique, and their electrochemical performance as anode for lithium-ion battery", *Electrochimica Acta* **55**, 504 (2009).
12. M. M. Rahman, J. Z. Wang, D. Wexler, Y. Y. Zhang, X. J. Li, S. L. Chou, and H. K. Liu, "Silver-coated TiO_2 nanostructured anode materials for lithium ion batteries", *Journal of Solid State Electrochemistry* **14**, 571 (2010).
13. M. M. Rahman, S. L. Chou, C. Zhong, J. Z. Wang, D. Wexler, and H. K. Liu, "Spray pyrolyzed NiO-C nanocomposite negative electrode for lithium-ion battery", Solid State Ionics 180, 1646 (2010).

Discovery Projects

Exploration for new materials for spintronics

Funded: 2005 2006 2007 2008 2009
Project ID: DP0558753

Chief Investigator: X. L. Wang

Progress made in 2009

1) We report on our observations on colossal electroresistance (ER) and giant magnetoresistance (MR) in doped $PbPbO_2$ thin films fabricated using pulsed laser deposition. A metal-insulator transition is observed at T_{MI} = 240 K, which decreases with increasing electrical current. The resistivity is strongly suppressed by the current below the T_{MI}, while it remains constant above the T_{MI}. The ER values, defined as ER ($[\Delta\rho/\rho_L = (\rho_H-\rho_L)/\rho_H)]$ x 100%, where ρ_L and ρ_H are the resistance at the lowest and highest current examined, respectively, can reach from 10^3 up to 10^7. These values are much greater than what have been achieved in manganese based colossal magnetoresistance (CMR) materials. Furthermore, giant positive or negative magnetoresistance with MR values of up to -100% or +175 % was also observed in magnetic fields up to 8.7 T over a wide temperature range from room temperature down to 5 K. The above observations are briefly discussed, based on the spin gapless band structure predicted by first-principles calculations for this compound. It is proposed that the change in the charge density due to change in the Fermi level, which is very sensitive to external conditions, is responsible for the observed colossal electroresistance and giant magnetoresistance. This also provides an alternative interpretation for the electroresistance observed in colossal magnetoresistance manganite perovskite compounds. *This work has been published in Advanced Materials. X. L. Wang, G. Peleckis, S. X. Dou, C. Zhang, H. Kimura, Advanced Materials 21, 2196 (2009).*

2) A review article was finished on a new class of materials "zero-gap materials". Electrons carry both charge and spin. The processing of information in conventional electronic devices is based only on the charge of the electrons. Spin electronics, or spintronics, uses the spin of electrons, as well as their charge, to process information. Metals, semiconductors and insulators are the basic materials that constitute the components of electronic devices, and these have been transforming all aspects of society for over a century. In contrast, magnetic metals, half-metals, magnetic semiconductors, dilute magnetic semiconductors and magnetic insulators are the materials that will form the basis for spintronic devices. Materials having a zero-energy band gap are a special class of these materials that exhibit some fascinating and superior electronic properties compared to materials with a non-zero energy gap. This article reviews a range of materials with zero-gap band structures, focusing on materials with quadratic and linear symmetrical dispersions, disorder-induced linear dispersions, asymmetrical linear dispersions and topological insulating states. These materials all have intriguing physical properties and numerous potential practical applications in spintronics, electronics, optics and sensors. *This work has been published in Nature Publishing Group Asia Materials. X. L. Wang, S. X. Dou, C. Zhang, [Review Article], "Zero-gap materials for future spintronics, electronics and optics", Nature Publishing Group, Asia Mater. 2(1) 31–38 (2010). This paper has been advertised several times by Nature in early 2010.*

3) Under the support of the QEII project, we have carried out a pioneering study on the newly discovered Fe-based superconductors. We measured the initial M-H curves for a sample of the newly discovered superconductor $NdFeAsO_{0.82}Fe_{0.18}$, which had a critical temperature, T_c, of 51 K, and was fabricated at the high pressure of 6 GPa. The lower critical field, H_{c1}, was extracted from the deviation point of the Meissner linearity in the M-H curves, which show linear temperature dependence in the low temperature region down to 5 K. The H_{c1}(T) indicates no s-wave superconductivity, but rather an unconventional superconductivity with a nodal gap structure. Furthermore, the linearity of H_{c1} at low temperature does not hold at high temperature, but shows other characteristics, indicating that this superconductor might have multi-gap features. Based on the low temperature nodal gap structure, we estimate that the maximum gap magnitude $\Delta_0 = (1.6 \pm 0.2)\ k_B T_c$. *This work was published in Journal of Physics: Condensed Matter. X. L. Wang, S. X. Dou, Z.-A. Ren, W. Yi, Z.-C. Li, Z.-X. Zhao, S.-I. Lee, "Unconventional superconductivity of $NdFeAsO_{0.82}F_{0.18}$ indicated by the low temperature dependence of the lower critical field H_{c1}, Journal of Physics: Condensed Matter, 21, 205701 (2009).*

Current limiting mechanisms in magnesium diboride superconductors

Funded: 2007 2008 2009 2010 2011
Project ID: DP0770205
Chief Investigators: S. X. Dou,

Partner Investigators: J. Driscoll, R. Flukiger, H. Kumakura, M. Sumption

Progress made in 2009

1) A universal relation between superconducting transition width and magnetic field in MgB_2 ceramics. A systematic study on the superconducting transition width as a function of the applied magnetic field was performed in MgB_2 ceramics. A quantitative, yet universal relation between the two parameters was observed in all of the ceramics. It was found that the width decreases linearly with decreasing field in pure MgB_2 samples. Whereas, samples with boron atoms partially replaced by other elements show this linear relation in the temperature range below 0.7 – 0.8 of the superconducting transition temperature (corresponding to a field of about 2 T), at temperatures higher than this range, an abnormal upturn in the width was found. This upturn is ascribed to multiple superconducting transitions. A core-shell model is proposed to describe the multiple transitions.

2) Determination of the relative influences of carbon doping and disorder on field and temperature dependent critical current density of MgB_2. It has been shown that the H_{irr} and H_{c2} (T < 28K) are higher in samples made by one-step reaction of SiC and Mg + 2B compared to two-step reaction whereby a pre-reaction of SiC + Mg is undertaken. More Mg_2Si is present for the one-step reaction, and consequently this leads to greater C substitution for B in MgB_2 as evidenced by a smaller *a*-axis of MgB_2. The greater C content leads to increased scattering from the C and associated defects and explains the improved magnetic behaviour observed. In terms of pinning, for the temperatures and fields studied, carbon enhances $J_c(H)$ only at 6K and for fields above 4T, but not at any field at 20K. At both 6K and 20K for fields below 7T, pinning overwhelmingly dominates $J_c(H)$. Lower reaction temperatures and short reaction times (e.g. 650°C and 30 min., as used here) are crucial for enhancing $J_c(H)$ through creation of pinning centres in the form of intra-grain and inter-grain disorder.

3) Impedance analysis of nano BN-doped MgB_2. We have performed detailed impedance analysis of nano BN-doped MgB_2. We find that: (1) the charge carriers in BN-doped MgB_2 are free ones. This leads to the notable inductance effect and an inductance-capacitance resonance in the measuring system. (2) A dielectric relaxation associated with the grain boundaries was detected in the measuring frequency window. The relaxation follows a field activated Arrhenius behaviour. These results provide useful information for a better understanding of the important topics related to grain boundaries in MgB_2, such as inter-grain connectivity, grain boundary pinning, etc. and these will be the theme of further studies.

Publications

1. T. G. Lee, M. Ranot, W. K. Seong, S. G. Jung, W. N. Kang, J. H. Joo, C. J. Kim, B. H. Jun, Y. Kim, Y. Zhao, S. X. Dou, "Fabrication of superconducting MgB_2 thin films on textured Cu(100) tape by hybrid physical-chemical vapour deposition", *Superconductor Science & Technology* **22**, 045006 (2009).
2. R. Zeng, S. X. Dou, L. Lu, W. X. Li, J. H. Kim, P. Munroe, R. K. Zheng, S. P. Ringer, "Thermal-strain-induced enhancement of electromagnetic properties of SiC-MgB_2 composites", *Applied Physics Letters* **94**, 042510 (2009).
3. Y. Zhang, S. H. Zhou, C. Lu, K. Konstantinov, S. X. Dou, "The effect of carbon doping on the upper critical field (H-c2) and resistivity of MgB_2 by using sucrose ($C_{12}H_{22}O_{11}$) as the carbon source", *Superconductor Science & Technology* **22**, 015025 (2009).
4. X. Xu, J. H. Kim, S. X. Dou, S. Choi, J. H. Lee, H. W. Park, M. Rindfleish, M. Tomsic, "A correlation between transport current density and grain connectivity in MgB_2/Fe wire made from ball-milled boron", *Journal of Applied Physics* **105**, 103913 (2009).
5. S. G. Jung, S. W. Park, W. K. Seong, M. Ranot, W. N. Kang, Y. Zhao, S. X. Dou, "A simple method for the enhancement of J(c) in MgB_2 thick films with an amorphous SiC impurity layer", *Superconductor Science & Technology* **22**, 075010 (2009).
6. M. S. A. Hossain, C. Senatore, R. Flukiger, M. A. Rindfleish, M. J. Tomsic, J. H. Kim, S. X. Dou, "The enhanced J(c) and B-irr of in situ MgB_2 wires and tapes alloyed with $C_4H_6O_5$ (malic acid) after cold high pressure densification", *Superconductor Science & Technology* **22**, 095004 (2009).
7. S. K. Chen, X. Xu, J. H. Kim, S. X. Dou, J. L. MacManus-Driscoll, "Determination of the relative influences of carbon doping and disorder on field and temperature dependent critical current density of MgB_2", *Superconductor Science & Technology* **22**, 125005 (2009).

First principles for development of novel hybrid electrochemical energy storage and conversion systems

Funded:	2007 2008 2009 2010 2011
Project ID:	DP0772999
Chief Investigators:	G. X. Wang, K. K. Konstantinov, C. Zhang, J. Z. Wang
Partner Investigators:	M. S. Islam, R. S. Liu, P. Novak, P. H. Notten

Progress made in 2009

This research project has proceeded as planned. The achievements and outcomes are summarized as follows:

1) α-Fe_2O_3 nanorods were synthesized by a facile hydrothermal method. The as-prepared α-Fe_2O_3 nanorods have a high quality crystalline nanostructure with diameters in the range of 60 – 80 nm and lengths extending from 300 nm to 500 nm. The crystal structure of α-Fe_2O_3 nanorods was characterized by X-ray diffraction (XRD), scanning electron microscopy (SEM) and transmission electron microscopy (TEM). α-Fe_2O_3 nanorod anodes exhibit a stable specific capacity of 800 mAh/g, showing a significantly improved electrochemical performance compared to that of commercial microcrystalline α-Fe_2O_3 powders in lithium-ion cells.

2) Nanoporous cobalt oxide nanorods were synthesized by a hydrothermal method. Transmission electron microscopy analysis showed that the individual Co_3O_4 nanorods have a nanoporous structure, consisting of the textured aggregations of nanocrystals. Optical properties of Co_3O_4 nanorods were characterized by Raman and UV-Vis spectroscopy. Magnetic property measurement shows that Co_3O_4 nanorods have a low Néel transition temperature of 35 K. We observed quite significant exchange bias for nanoporous Co_3O_4 nanorods, indicating the existence of magnetic coupling between the nanocrystals in Co_3O_4 nanorods. When applied as electrode materials in supercapacitors, Co_3O_4 demonstrated a high capacitance of 280 F/g.

3) Nano-structured Vanadium Pentoxide/Carbon (V_2O_5/Carbon) composite powders were synthesized for the first time by spray pyrolysis technique for electrochemical capacitor electrode material. The as-prepared material is systematically tested for its morphology features and electrochemical characteristics. Nano-sized porous structure of 5-50 nm and a specific surface-area 18 m^2/g were shown as the results of the TEM and BET measurements, respectively. The electrochemical properties were examined by the Cyclic Voltammetry technique and the composite powders yielded a maximum specific capacitance of 295 F g^{-1} in 2M KCl electrolyte at 5 mV s^{-1} scan rate. The weight percentage of carbon, 7.8wt% in the V_2O_5/Carbon composite, was detected by EDS and confirmed by TGA. The enhancement of the specific capacitance was affected by the presence of carbon, as the conductivity was increased.

4) Graphene nanosheets were synthesized in large quantities using a chemical approach. Field emission electron microscope observation revealed that loose graphene nanosheets agglomerated and crumpled naturally into shapes resembling flower-petals. High resolution transmission electron microscope analysis, Raman spectroscopy and ultraviolet-visible spectroscopy measurements confirmed the graphitic crystalline structure of the graphene nanosheets. The nanosheets exhibited an enhanced lithium storage capacity as anodes in lithium-ion cells and good cyclic performance.

Publications

1. H. Liu, G. Wang, J. Park, J. Wang, H.K. Liu, C. Zhang, "Electrochemical performance of α-Fe_2O_3 nanorods as anode material for lithium-ion cells", *Electrochimica Acta* **54**, 1733 (2009).
2. B. Wang, K. Konstantinov, G. Wang, D. Wexler, H. Liu, "Synthesis of nanosized vanadium pentoxide/carbon composites by spray pyrolysis for electrochemical capacitor application", *Electrochimica Acta* **54**, 1420 (2009).
3. G. Wang, X. Shen, J. Horvat, B. Wang, H. Liu, D. Wexler, J. Yao, "Hydrothermal synthesis, optical, magnetic and supercapacitance properties of nanoporous cobalt oxide nanorods", *The Journal of Physical Chemistry C* **113**, 4357 (2009).
4. J. Yao, X. Shen, B. Wang, H.K. Liu, G. Wang, "In situ Chemical synthesis of SnO_2-graphene nanocomposite as anode materials for lithium-ion batteries", *Electrochemistry Communications* **11**, 1849 (2009).

New concepts with multidisciplinary approach: novel functionalised nanostructures for hydrogen storage

Funded: 2007 2008 2009
Project ID: DP0771193
Chief Investigators: Z. P. Guo, H. K. Liu
Partner Investigators: P. H. Notten, J. Chen, A. Zuettel

Progress made in 2009

MgH_2-SiC-Ni was prepared by magneto-mechanical milling in hydrogen atmosphere. Scanning electron microscope mapping images showed a homogeneous dispersion of both Ni and SiC among MgH_2 particles. Based on the differential scanning calorimetry traces, the temperature of desorption is reduced by doping MgH_2 with SiC and Ni. Hydrogen absorption/desorption behaviour of the samples was investigated by Sievert's method at 300 °C, and the results showed that both capacity and kinetics were improved by adding SiC and Ni. The hydrogen desorption kinetic investigation indicated that for pure MgH_2, the rate-determining step is surface controlled and recombination, while for the MgH_2-SiC-Ni sample it is controlled as described by the Johnson-Mehl-Avrami 3D model (JMA 3D).

The hydrogen storage properties of $2NaBH_4 + MgH_2$ system were studied. It was found that the presence of MgH_2 could destabilize the decomposition of $NaBH_4$, decreasing the dehydrogenation temperature about 40 °C compared with the pure $NaBH_4$. It is believed that the formation of MgB_2 upon dehydrogenation stabilizes the dehydrogenated state and, thereby, destabilizes the $NaBH_4$. For desorption, the following two-step reaction was observed: $2NaBH_4 + MgH_2 \rightarrow 2NaBH_4 + Mg + H_2 \rightarrow 2NaH + MgB_2 + 4H_2$.

Furthermore, various catalysts such as TiF_3, TiO_2, Zr, Si and BCC alloy were doped to the $NaBH_4$-MgH_2 system. Among these catalysts, TiF_3 exhibited the optimum behaviour in terms of fast kinetics and lowering the dehydrogenation temperature of the $NaBH_4$-MgH_2 system. The rehydrogenation experiments of TiF_3-doped $NaBH_4$-MgH_2 system were investigated at 600 °C with an initial hydrogen pressure of about 4 MPa. It showed that 5.89 wt. % hydrogen was rehydrogenated within 12h. XRD results demonstrated the formation of $NaBH_4$ and MgH_2 in the rehydrogenated sample.

We have demonstrated the proof-of-principle that interaction between visible light and a magnesium hydride sample in reflective mode can be used to determine desorption temperature and kinetics of magnesium hydride in powder form. The demonstrated optical technique requires only milligrams of sample and can potentially be used to measure the de/absorption temperature and kinetics of magnesium nanostructures, which are often fabricated via the physical vapour deposition method inside an optically transparent quartz tube. This would help to eliminate the common problem of oxidation associated with removal and transport of the freshly fabricated nanostructures into an inert protective environment. This optical technique could be applied to any hydrogen-storage material in the form of powder which shows a significant difference in its optical absorption between the hydride and the non-hydride phase.

Publications

1. A. Ranjbar, Z. P. Guo, X. B. Yu, A. Calka, H. K. Liu, "Hydrogen storage properties of Mg-BCC composite", *International Journal of Green Energy* **6**, 607 (2009).
2. J. F. Mao, Z. P. Guo, H. K. Liu, X. B. Yu, "Reversible hydrogen storage in titanium-catalysed $LiAlH_4$-$LiBH_4$ system", *Journal of Alloys and Compounds* **487**, 434 (2009).
3. C. K. Poh, Z. P. Guo, H. K. Liu, Measurement of desorption temperature and kinetics of powdery magnesium hydride via optical technique", *International Journal of Hydrogen Energy* **34**, 9168 (2009).
4. A. Ranjbar, Z. P. Guo, X. B. Yu, D. Wexler, A. Calka, C. J. Kim, H. K. Liu, "Hydrogen storage properties of MgH_2-SiC composites", *Materials Chemistry and Physics* **114**, 168 (2009).
5. A. Ranjbar, Z. P. Guo, X. B. Yu, A. Calka, H. K. Liu, "Effects of SiC nanoparticles with and without Ni on the hydrogen storage properties of MgH_2", *International Journal of Hydrogen Energy* **34**, 7263 (2009).
6. J. F. Mao, X. B. Yu, Z. P. Guo, H. K. Liu, Z. Wu, "Enhanced hydrogen storage performances of $NaBH_4$-MgH_2 system", *Journal of Alloys and Compounds* **479**, 619 (2009).
7. H. B. Lu, C. K. Poh, Z. P. Guo, X. B. Yu, H. K. Liu, "Dehydrogenation characteristics of Ti- and Ni/Ti-catalysed Mg hydrides", *Journal of Alloys and Compounds* **481**, 152 (2009).

Development of novel high efficiency thermoelectric oxides for high temperature power generation

Funded: 2008 2009 2010
Project ID: DP0879714
Chief Investigators: G. Peleckis

Progress made in 2009

The project proceeded without any major interruptions. We have continued our investigations on the preparation and formation of sodium cobalt oxide single crystals. It was found that single crystal formation occurs when parent sodium cobalt bronze is doped with larger alkali metals, such as potassium or rubidium. Our investigations showed that only in the case of potassium doping formation of single crystals occurs. Two types of single crystals are formed upon sintering alkali metal doped samples: whisker type crystals (these are one dimensional single crystals) and plate like single crystals. The plate-like single crystals were found to be very thin and highly fragile and thus not suitable for further investigations and experimental processes. The necessary conditions for the formation of maximum amount of whisker type single crystals were investigated. The ratio of the formed single crystals can be controlled by the amount of the dopant and sintering temperature. It was found that the optimal condition for the formation of large number of whisker single crystals is when potassium doping level is about 25%, while sintering temperature is 875 ºC. The formation of the crystals is very fast and the bulk of the crystals' is formed during first two hours of sintering. Rubidium doping did not show formation of any form of single crystalline structures on the surface of the pellets. Rb doped samples were found to be extremely hygroscopic and adsorb large amounts of moisture. Furthermore, the stability of the triple phase, *i.e.* Na-Rb-Co is very low. As compared to the potassium doped phase, the stability region for Rb doped phase is 100 ºC smaller than K counterpart. Physical properties measured showed, that Rb doped samples have largest electrical resistivity and that magnetoresistance (MR) in these samples is very low (MR ~ 0.5%) as compared to MR = 7% and MR = 12% at 5 K, for potassium doped and undoped sodium cobalt oxide, respectively. Furthermore, typical irreversibility observed in the electrical resistivity curves at room temperature was not observed in Rb doped samples and it was quite significantly suppressed in K doped samples. This might indicate that large alkali metal ions create barriers for Na ions to migrate in the intra-layers of the crystal structure. This finding is important, because sodium migration causes degradation of the electrical conductivity at high temperatures with time.

Bulk $Ca_3Co_4O_9$ (Ca-349) samples have been prepared by a conventional solid state synthesis, sol-gel and hydrothermal methods. The main goal of the research work on this compound was to investigate thermoelectric performance of Ca-349 bulks based on nano-particle precursors. Nano-particles are extremely important to increase phonon scattering, *i.e.* decrease thermal conductivity, due to the formation of multiple grain boundaries. As a result of conventional solid state synthesis, the size of the crystallites in the samples is averaging several tenths of micrometers. On the other hand the precursor materials prepared by sol-gel synthesis showed that the crystallites are about 100 nm in size. Unfortunately, during the sintering of the final bulk pellets, crystallites tend to agglomerate and form larger particles, *i.e.* 10-50 μm. Therefore, we have explored possibility of adding surfactant to the solution, which would decompose during sintering process, but would prevent particles to agglomerate. Our findings showed that addition of the surfactant indeed decreases particle size to nanometre size during initial step of the synthesis, however, after sintering the particle size is still in μm range and impurities originating from the decomposition of the surfactant were also identified. These impurities cause increase of electrical resistance of the samples, which diminish the effect of improved phonon scattering in the samples. The thermoelectric properties of the samples showed that Seebeck coefficient at room temperature is ~135 μV/K, which is very well comparable to literature data. However, electrical resistivity is twice as high as standard solid state synthesis samples. Thermal conductivity (κ) measured showed decrease from 50 $Wm^{-1}K^{-1}$ to 10-15 $Wm^{-1}K^{-1}$.

Pure and Ga doped ZnO samples were formed by conventional solid state synthesis technique and by applying high energy dry and wet ball milling. Obtained results indicated that all samples correspond to

hexagonal ZnO phase, with secondary impurities below 1%. High energy ball milling was proved to be a very efficient technique to form nano-particle based precursors. The best conditions for the development of the nano-particles was found to be wet milling at 900 rpm. The particle size of so formed precursors was in order of several tenths of nanometres. Furthermore, the distribution of the elements in the material was very uniform as per SEM-EDS observations. After sintering high energy ball milled samples showed very dense microstructure with apparent voids or holes penetrating the body of the sample. This was very different from the samples prepared by conventional solid state synthesis route, where crystallites within the bulk of the samples could be easily identified and the samples were quite porous. The voids in ball milled samples can act as effective phonon scattering centres. High temperature thermoelectric properties showed significant increase of thermoelectric power factor, which was found to be 26 times larger than for the pure ZnO. The Seebeck coefficient at 1000 K was -185 μV/K, which is quite large compared to the Seebeck coefficient values for the same compound reported in the literature. Although thermoelectric properties of Ga-doped ZnO have been considerably enhanced, ZT of the material at room temperature is still in the order of 10^{-3}, which 2 orders of magnitude lower than for the *p*-type thermoelectric oxide counterparts.

Publications

1. P. Jood, G. Peleckis, X. L. Wang, S. X. Dou, H. Yamauchi, and M. Karppinen, "Phase formation and magnetotransport of alkali metal doped $Na_{0.75}CoO_2$ thermoelectric oxide", *Journal of Applied Physics* **107**, 09D716 (2010).

Giant Magnetocaloric Materials and Room Temperature Refrigeration

Funded: 2008 2009 2010 2011
Project ID: DP0879070
Chief Investigators: S. X. Dou, J. H. Kim, T. H. Johansen, E. Bruck

Progress made in 2009

In this year, we have synthesized various alloys, oxides and nanomaterials, the magnetic properties, magnetic phase structures and transitions, magnetocaloric properties have been characterized. The main results are listed below:

1) Magnetic properties and magnetocaloric effect of $(Mn_{1-x}Ni_x)_3Sn_2$ (x=0–0.5) compounds. The effects of Ni substitution on the magnetic properties and magnetocaloric effect (MCE) of $(Mn_{1-x}Ni_x)_3Sn_2$ compounds x=0–0.5 have been investigated by x-ray diffraction and magnetization measurements. It was found that Ni substitution decreases the crystal cell volume and the magnetic transition temperatures compared with pure Mn_3Sn_2. The MCE for all samples has been calculated from the magnetization data in terms of the isothermal magnetic entropy change (ΔS_M). The maximum values of ΔS_M max at the magnetic phase transition temperatures resulting from a change in magnetic field of $\_H$=5 T were found to be 28.2 mJ/cm^3 K for Mn_3Sn_2 T_{C1}~257 K, increasing to 31.2 mJ/cm^3 K for $(Mn_{0.9}Ni_{0.1})_3Sn_2$ T_C~167 K.

2) Re-entrant ferromagnet $PrMn_2Ge_{0.8}Si_{1.2}$: Magnetocaloric effect. The structural and magnetic properties of the re-entrant ferromagnet $PrMn_2Ge_{0.8}Si_{1.2}$ have been investigated by various experimental methods. Similar to the canonical re-entrant ferromagnet $SmMn_2Ge_2$, multiple magnetic phase transitions have been detected in $PrMn_2Ge_{0.8}Si_{1.2}$ over the temperature range from 10 to 550 K with re-entrant ferromagnetism occurring around ~54 K. The magnetocaloric effect has been measured in terms of the isothermal magnetocaloric entropy change and found to be positive at the re-entrant ferromagnetic transition with a maximum value of around 1.9 J/kg K at 58 K for a magnetic field change of 0–3 T. On the other hand, the entropy change becomes negative (~ −0.5 J/kg K) at the antiferromagnetic to ferromagnetic transition for the same field change.

3) Magnetic phase transitions in $Pr_{1-x}Lu_xMn_2Ge_2$ compounds. The effects of replacing Pr by Lu on the magnetic behaviour and structures of $Pr_{1-x}Lu_xMn_2Ge_2$ (x = 0.2, x = 0.4) have been investigated using x-ray diffraction, Mossbauer spectroscopy, magnetization and neutron diffraction measurements. The substitution of Lu for Pr leads to a decrease in the lattice constants a, c and the unit cell volume V at room temperature with this contraction of the unit cell resulting in modifications of the $Pr_{1-x}Lu_xMn_2Ge_2$

magnetic structures. Four and five magnetic phase transitions—linked primarily with temperature driven changes in the intra-layer Mn–Mn separation distances—have been detected within the temperature range 4.5–550 K for $Pr_{0.8}Lu_{0.2}Mn_2Ge_2$ and $Pr_{0.6}Lu_{0.4}Mn_2Ge_2$, respectively, with re-entrant ferromagnetism being detected around $T_{Pr\ C} \sim 31$ K for $Pr_{0.6}Lu_{0.4}Mn_2Ge_2$. It was found that T inter C and T_{PrC} increase with increasing applied field while T inter N decreases for $Pr_{0.6}Lu_{0.4}Mn_2Ge_2$, indicating that the canted antiferromagnetic AFmc region contracts with increasing field. The Debye temperatures for $Pr_{1-x}Lu_xMn_2Ge_2$ with $x = 0.2$ and 0.4 were evaluated as $\theta_D = 320 \pm 40$ K and $\theta_D = 400 \pm 20$ K respectively from the temperature dependence of the average isomer shift. The magnetic structures of both compounds have been determined by means of neutron diffraction measurements over the temperature range 3–300 K with formation of the Fmi magnetic state below $Tc/c = 192$ K for $Pr_{0.8}Lu_{0.2}Mn_2Ge_2$ and the occurrence of re-entrant ferromagnetism below $T_{Pr\ C} = 31$ K for $Pr_{0.6}Lu_{0.4}Mn_2Ge_2$ being confirmed.

4) Giant magnetic entropy change in colossal magnetoresistance $La_{0.7}Ca_{0.3}MnO_3$ material in low field. The structural, magnetic, and magnetocaloric properties of the manganite $La_{0.7}Ca_{0.3}MnO_3$ have been studied. Change in the giant magnetic entropy was observed without any noticeable magnetic hysteresis but with small thermal hysteresis losses. We observed a first order magnetic phase transition around 251 K. The magnetic entropy change observed in this work is estimated to be 5.27 J/kg K for field changes from 0 to 1.5 T based on magnetization measurements. This value is about twice as large as those for other perovskite manganites and is even larger than for Gd-based magnetic materials at low fields. In addition, the entropy change was estimated by using the heat capacity method, which can be well explained by the Maxwell relation.

Tailoring superconducting hybrid multilayered film systems for electric and electronic applications

Funded:	2008 2009 2010 2011 2012
Project ID:	DP0879933
Chief Investigators:	A. V. Pan
Partner Investigators:	C. Foley, T. H. Johansen, H. Hilgenkamp

Progress made in 2009

The main aim of the project is to develop new superconducting systems and junctions, exhibiting novel properties and phenomena for various applications, ranging from quantum electronics to effective charge transport.

Multilayered Josephson Junctions have been obtained extensively using collaboration with PI (Foley) at CSIRO and its clean room facility. Preliminary results indicate that multilayered YBCO Josephson Junctions better than monolayered ones fabricated at the same conditions.

Vortex pinning mechanism at boundaries with modulated pinning potentials is developed for high quality $YBa_2Cu_3O_7$ superconducting films and multilayers. This mechanism accurately describes the experimental critical current behaviour in different films and multilayers. A supplementary "model-free" analysis of the temperature dependent critical current density curves leads to the four regions in the field-temperature phase diagram which are attributable to the well-known pinning regimes of collective pinning theory. The results obtained indicate the universality of the pinning model developed.

The recently proposed model explaining the sophisticated magnetic behaviour in Ruthenium (Ru) based superconducting ferromagnets has been extended to deal with all the observed effects at all temperature ranges. The complex system of Ru-materials, always consisting of at least two interacting magnetic species and multiple magnetic transitions, has been explained. The superposition of corresponding ferromagnetic signals has been proposed to be responsible for producing features compatible with spin glasses, super-paramagnetism, ferromagnetism, and antiferromagnetism. In our work, the combination of microstructural, magnetic and transport measurements along with careful analysis of the nonlinear ac-susceptibility has allowed us to understand the spin ordering in these cluster systems, and establish the cohesive model working in the entire temperature and field range.

Comprehensive comparative analysis of structural and electromagnetic characteristics have been performed on nano SiC- and polycarbosilane-doped MgB_2 samples prepared by the dry and liquid mixing approaches. The total benefit of liquid mixing approach for fabrication of "organic" MgB_2 superconductor with excellent electromagnetic performance has been demonstrated. Accordingly, polycarbosilane has been found to be an optimal dopant for MgB_2 superconductor, producing the largest critical current density. As a result of this comprehensive work, a book has been published.

Publications

Book:

1. O. V. Shcherbakova, A. V. Pan, S. X Dou, "Magnesium diboride superconductors: development and properties", VDM Verlag Dr. MuellerAktiengesellschaft & Co. KG, Germany, USA, UK, 2009.

Refereed journal papers:

2. A. V. Pan, S. V. Pysarenko, S. Dou, Physica C (2009), doi: 10.1016/j.physc.2009.11.077, in press.
3. S. V. Pysarenko, A. V. Pan, S. X. Dou, R. Nigam, "Extended dislocation-based pinning mechanism in superconducting $YBa_2Cu_3O_7$ films", *Journal of Applied Physics* **107**, 09E118 (2010).
4. R. Nigam, A. V. Pan, and S. X. Dou, "Coexistence of ferromagnetism and cluster glass state in superconducting ferromagnet $RuSr_2Eu_{1.5}Ce_{0.5}Cu_2O_{10\text{-}delta}$", *Journal of Applied Physics* **105**, 07E303 (2009).
5. A. V. Pan, S. Pysarenko, and S. X. Dou, "Quantitative description of critical current density in YBCO films and multilayers", *IEEE Transactions on Applied Superconductivity* **19**, 3391 (2009).
6. R. Nigam, A. V. Pan, and S. X. Dou, "Comparative study of magnetic behaviour of $RuSr_2RE_{1.5}Ce_{0.5}Cu_2O_{10\text{-}delta}$, where RE = Eu and Sm" *International Journal of Modern Physics B* **23**, 3486 (2009).
7. R. Nigam, A. V. Pan, and S. X. Dou, "Cluster spin glass and super-paramagnetism in $RuSr_2Eu_{1.5}Ce_{0.5}Cu_2O_{10\text{-}(delta)}$", *European Physical Journal B* **74**, 429 (2010).
8. O. V. Shcherbakova, A. V. Pan, E. Babic, and S. X. Dou, *Journal of Physics*, accepted on 20/10/2009, *in press.*

Conference presentations:

1. A. V. Pan (invited), Superconducting thin films: fundamentals, progress and applications, International Energy Symposium, 18-20 November 2009, Wollongong, Australia

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Improvement and synthesis of advanced hydrogen storage materials for fuel cell applications

Funded: 2008 2009 2010
Project ID: DP0878661
Chief Investigators: X. B. Yu

Progress made in 2009

The effect of $Ti_{0.4}Cr_{0.15}Mn_{0.15}V_{0.3}$ alloy on the hydrogen storage properties of MgH_2 was investigated. It was found that the hydrogenated BCC alloy showed superior catalysis properties compared to the quenched and ingot samples. As an example, the 1 h milled MgH_2+20 wt. % hydrogenated BCC shows a peak temperature of dehydrogenation of about 294 ºC. This is 16, 27, and 74 ºC lower than those of MgH_2/quenched BCC, ingot BCC, and a neat MgH_2 sample, respectively. The activation energy, E_a, for the dehydrogenation of the MgH_2/hydrogenated BCC mixture was estimated to be about 71.2 kJ.mol H_2^{-1} from Kissinger plots. This represents a significant decrease compared to the pure MgH_2 (179.7 kJ.mol H_2^{-1}). This indicates that the catalytic effect of BCC doping significantly decreases the activation energy of MgH_2 for hydrogen desorption by surface activation. Cycling results revealed that the BCC catalysed MgH_2 showed good cycle life.

We have investigated the hydrogen storage properties of the $LiAlH_4$-$LiBH_4$ system, both un-doped and doped with titanium based catalysts. It was found that TiF_3 exhibited the superior catalytic effects in terms of enhancing the hydriding/dehydriding kinetics and reducing the dehydrogenation temperature of the $LiAlH_4$-$LiBH_4$ system. Compared to the un-doped $LiAlH_4$-$LiBH_4$ system, the onset temperatures of the 5 mol% TiF_3-doped sample for the first and second dehydrogenation steps were decreased by 64 and 150 degrees C, respectively.

The hydrogen storage properties of $LiBH_4$ ball milled with TiF_3 were investigated. It was found that the $LiBH_4$-TiF_3 mixture exhibited significantly improved dehydrogenation properties. For example, the

$LiBH_4$-TiF_3 (mole ratio:3:1) sample started to release hydrogen at around 100 °C, and the hydrogen desorption capacity reached to 5.0 wt. % at 250 °C. Furthermore, the dehydrogenated product can be rehydrogenated partly at 100 atm H_2 and 350 °C. XRD, IR and XPS characterizations revealed that the decreased dehydrogenation conditions in $LiBH_4$-TiF_3 system resulted from an exothermic reaction of $3LiBH_4+TiF_3 \rightarrow 3LiF+TiB_2+B+6H_2$, which improved both its thermodynamics and kinetics. As the above reaction is exothermic, the reverse reaction is not feasible, further investigations indicated that the rehydrogenation may be due to the formation of other borohydride.

The monoammoniate of lithium amidoborane, $Li(NH_3)NH_2BH_3$, was synthesized by reacting $LiNH_2BH_3$ with ammonia at room temperature. This compound is in the amorphous state at room temperature, but crystallizes in the orthorhombic space group Pbca under –20 ^oC with lattice parameters of a = 9.711(4) Å, b = 8.7027(5) Å, c = 7.1999(1) Å and V = 608.51 $Å^3$. The thermal decomposition performance of this compound was investigated under argon and ammonia atmosphere. By a series of experiments, we have demonstrated that $Li(NH_3)NH_2BH_3$ is able to absorb/desorb ammonia reversibly at room temperature. However, within the temperature range of 40 – 70 ^oC, this compound showed favourable dehydrogenation. Specifically, this material was able to release 3.01 equiv. hydrogen (11.18 wt. %)) rapidly at 60 ^oC under ammonia atmosphere, which is a significant advantage over $LiNH_2BH_3$. It has been found that the formation of the coordination bond between ammonia and Li^+ in $LiNH_2BH_3$ plays a crucial role in promoting the combination of hydridic B-H bonds and protic N-H bonds, leading to dehydrogenation at low temperature.

Publications

1. X. B. Yu, G. L. Xia, Z. P. Guo, et al. "Dehydrogenation/rehydrogenation mechanism in aluminum destabilized lithium borohydride", *Journal of Materials Research* **24**, 2720 (2009).
2. X. B. Yu, Y. H. Guo, Z. X. Yang, Z. P. Guo, H. K. Liu, and S. X. Dou, "Synthesis of catalysed magnesium hydride with low absorption/desorption temperature", *Scripta Materialia* **61**, 359 (2009).

Novel graphene nanostructures: modelling, synthesis, fabrication and characterization

Funded: 2008 2009 2010
Project ID: DP0879151
Chief Investigators: C. Zhang, D. Li

Progress made in 2009

Through theoretical analysis and simulation, we have revealed a class of bilayer graphene nanoribbons with extremely high optical response. These are armchair bilayer ribbons with strong nonsymmetric quantum transitions. The result has removed a major obstacle in applying graphene to low energy photonics.

We have determined the critical field required for the nonlinear effect to be dominant in graphene. This nonlinear effect can be used to enhance the light absorption and emission through up-conversion and down-conversion.

The effect of the next nearest neighbour coupling in bilayer graphene has been analysed and quantitatively calculated. The result provides a method for measuring the next nearest neighbour coupling in an optical experiment. We have shown that the mechanical strain in graphene can induces a strong transverse electromagnetic response.

We have discovered that by controlling the preparation conditions such as sonication power and time, the lateral size of graphene sheets can be controlled from tens of nanometres to tens of micrometers. We have found that the conductivity and electrochemical properties of graphene membranes can be tailored by controlling the corrugation of graphene sheets. We have found that silver nanoparticles can be grown on graphene sheets with controllable sizes and densities, demonstrating that graphene oxide is an unprecedented platform for the synthesis and dispersion of metal nanoparticles. We have preformed some preliminary experiments on electrochemical properties of graphene oxide and reduced graphene, showing very different behaviours from carbon nanotubes.

Publications

1. A. R. Wright, J. C. Cao, and C. Zhang, "Enhanced optical conductivity of bilayer graphene nanoribbons in the terahertz regime", *Physical Review Letters* **103**, 207401 (2009).
2. A. R. Wright and C. Zhang, "Stretching induced Hall current and conductance anisotropy in graphene", *Applied Physics Letters* **95**, 163104 (2009).
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5. S. Yang, D. Guo, L. Su, P. Yu, D. Li, J. Ye, L. Mao, "A facile method for preparation of graphene film electrodes with tailor-made dimensions with Vaseline as the insulating binder", *Electrochemistry Communications* **11**, 1912 (2009).
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7. A. R. Wright, G. X. Wang, W. Xu, Z. Zeng, C. Zhang, "The spin–orbit interaction enhanced terahertz absorption in graphene around the K point", *Microelectronics Journal* **40**, 857 (2009).

Charge transfer mechanism in 3-dimensional pore solid nanoarchitectures for electrochemical systems

Funded: 2008 2009 2010
Project ID: DP0878611
Chief Investigators: Z. P. Guo

Progress made in 2009

1) Three-dimensional (3D) reticular SnO_2 thin films deposited on copper and stainless steel substrates were prepared by the electrostatic spray deposition (ESD) technique. The 3D reticular SnO_2 film exhibit a high reversible capacity near 300 mAh g-1 up to the 50th cycle. The 3D reticular structure can provide a large amount of reaction sites on the electrode surface and accommodate volume variations of Sn particles during alloying and de-alloying. The 3D reticular SnO_2 thin film gives an important indication for the further improvement of the electrochemical properties that is possible with the SnO2 system.

2) Furthermore, a tin-cobalt oxide film with a 3-dimensional (3D) reticular structure has been prepared by electrostatic spray deposition (ESD). X-Ray diffraction (XRD) and transmission electron microscopy (TEM) make it clear that the film is amorphous. X-Ray photoemission spectroscopy (XPS) indicates that the 3D grid is composed of SnO_2 and CoO. The CoO in the complex composite film plays an important role, allowing the formation of a polymeric gel-like film to improve its electrochemical performance, preventing Sn aggregation during charging and discharging. Such a composite film can be used as an anode for lithium ion batteries with higher energy densities.

3) Ultra-fine porous SnO_2 nanoparticles for lithium ion batteries were prepared by a simple, easily scaled-up molten salt method at 300 °C. The as-prepared SnO_2 had a tetragonal rutile structure with crystal sizes around 5 nm. The electrochemical performance was tested compared with commercial nanopowder and previously reported nanowires. The as-prepared nanoparticles delivered a significantly higher discharge capacity and better cycle retention. The nanoparticle electrode delivered a reversible capacity of 410 mAh g-1 after 100 cycles. Even at high rates, the electrode operated at a good fraction of its capacity. The excellent electrochemical performance of the ultra-fine porous SnO_2 can be attributed to the ultra-fine crystallites (which tend to decrease the absolute volume changes) and the porous structure (which promotes liquid electrolyte diffusion into the bulk materials and acts as a buffer zone to absorb the volume changes).

4) $LiFePO_4$ thin films were deposited by radio frequency (RF) magnetron sputtering. The effect of substrate temperature during the RF magnetron sputtering on the morphology and characteristics of the $LiFePO_4$ thin films has been investigated. When the substrate temperature increased, the film structure changed from amorphous to crystalline, as characterized by X-ray diffraction. At the high substrate temperature of 500 °C, an impurity phase of $Li_3Fe_2(PO_4)_3$ was developed, and carbon particles in the film tended to aggregate in clusters on the substrate surface. The surface and cross-sectional morphology of the thin film was observed by using scanning electron microscopy. Electrochemical tests

showed that the different characteristics of the as-deposited films could be attributed to the crystallography and morphology.

Publications

1. Z. P. Guo, G. D. Du, Y. Nuli, M. Hossan, H. K. Liu, "Ultrafine porous SnO_2 nanopowders prepared via molten salt process: a highly efficient anode material for lithium-ion batteries", *Journal of Materials Chemistry* **19**, 3253 (2009).
2. X. J. Zhu, L. B. Cheng, C. G. Wang, Z. P. Guo, P. Zhang, G. D. Du, H. K. Liu, *Journal of Physical Chemistry C* **113**, 14518 (2009).
3. D. M. Han, Z. P. Guo, R. Zeng, C. J. Kim, Y. Z. Meng, H. K. Liu, "Multiwalled carbon nanotube-supported Pt/Sn and Pt/Sn/PMo_{12} electrocatalysts for methanol electro-oxidation", *International Journal of Hydrogen Energy* **34**, 2426 (2009).
4. Y. L. Qi, Y. D. Huang, D. Z. Jia, S. J. Bao, Z. P. Guo, "Preparation and characterization of novel spinel $Li_4Ti_5O_{12-x}Br_x$ anode materials", *Electrochimica Acta* **54**, 4772 (2009).
5. X. J. Zhu, Z. P. Guo, P. Zhang, G. D. Du, R. Zeng, Z. X. Chen, H. K. Liu, "Tin oxide thin film with three-dimensional ordered reticular morphology as a lithium ion battery anode", *Chemical Physics: Chemistry* **10**, 3101 (2009).
6. X. J. Zhu, Z. P. Guo, P. Zhang, G. D. Du, R. Zeng, Z. X. Chen, S. Li, H. K. Liu, "Highly porous reticular tin-cobalt oxide composite thin film anodes for lithium ion batteries", *Journal of Materials Chemistry* **19**, 8360 (2009).
7. C. Q. Feng, J. Ma, H. Li, R. Zeng, Z. P. Guo, H. K. Liu, "Synthesis of molybdenum disulfide (MoS_2) for lithium ion battery applications", *Materials Research Bulletin* **44**, 1811 (2009).

Fabrication of high quality MgB_2 superconductor

Funded: 2008 2009 2010
Project ID: DP0879843
Chief Investigators: S. H. Zhou

Progress made in 2009

To improve the critical current density and critical magnetic field is the task for the project. Five tasks were carried out during the year.

A $SiCl_4$ was used to dope inside the MgB_2, although the nano SiO_2 particles resulting from the reaction of $SiCl_4$ and moisture can act as pinning centres, the Jc decreased as a consequence of the damage caused by HCl.

$C_4H_6O_4Zn$ was added to MgB_2 as dopant, it was found the dopant had a marked effect on the crystal lattice parameters, the critical temperature of the samples decreased with increasing $C_4H_6O_4Zn$ addition, but the rate of decrease was slower than for those samples doped with carbon only. The normalized volume pinning force density increases after the doping.

MgB_2 was co-doped with Fe and C by adding iron (II) lactate ($C_6H_{10}FeO_6$), the phase composition, microstructure and superconducting properties were studied, it was found that the Fe elements were distributed uniformly in the MgB_2 matrix. The residual resistivity ration was decreased as the $C_6H_{10}FeO_6$ doping level increased. The critical temperature decreased with increased doping level, as did the critical current density. MgO amount increases as a consequence of the decomposition of the organic compound.

A purifying process was used to remove B_2O_3 from the oxidized B powder, the sample made with purified B powder show higher Jc. The improvement of the Jc was attributed to the removal of the B_2O_3 from the B powder, and correspondingly, causing less MgO in the MgB_2 during the later sintering.

Silicon oil was used for doping into MgB_2, Jc was improved compared with the undoped samples. The tiny particle resulting from the decomposition of the silicon oil at high temperature could be flux pinning centres. The carbon from the silicon oil improved the Hc_2.

Publications

1. S. H. Zhou and S. X. Dou, "Properties of MgB_2 bulks after combined doping with Fe and C by adding Iron (II) lactate ($C_6H_{10}FeO_6$)", *Solid State Sciences* **12**, 105 (2010).
2. S. H. Zhou, Y. Zhang, S. X. Dou, "Effects of B_2O_3 in precursor B powder on MgB_2 critical current density", *Physica C In press*, Available online 27 October 2009
3. S. H. Zhou, A. V. Pan, and S. X. Dou, "An attempt to improve the superconducting properties of MgB_2 by doping with Zn-containing organic compound", *Journal of Alloys and Compounds* **487**, 42 (2009).

Frustrated magnets: a new platform for multiferroic materials

Funded: 2009 2010 2011
Project ID: DP0987190
Chief Investigators: X. L. Wang, Z. X. Cheng, D. P. Chen, T. Kimura, F. Klose

Progress made in 2009

1) Multiferroic properties of two rare earth chromates. $GdCrO_3$ and $YCrO_3$ were studied. Polycrystalline bulks and thin films have been fabricated using conventional solid state reaction and pulsed laser deposition. Magnetic measurements have revealed that both compounds show weak ferromagnetism below the antiferromagnetic Neel temperature, TN, of 170 and 140 K for $GdCrO_3$ and $YCrO_3$, respectively. However the well-developed ferroelectric polarization electrical field loop was not successfully measured for both samples due to their low resistance. The high conductivity of the samples at room temperature is related to the thermal activation of charge carriers at around 200 K in the samples revealed by temperature dependent dielectric measurement. Capacitance measurement at 77 K within magnetic field of 3000Oe and zero field for $GdCrO_3$ bulk sample shows an increase of 58% in capacitance at 400 kHz by a magnetic field.

2) The effects of La doping on the structure and magnetic properties of $DyFeO_3$. XRD refinement and Raman spectroscopy revealed that the crystal structure of $Dy_{1-x}La_xFeO_3$ (x = 0.0, 0.1, 0.2, 0.3, and 0.4) is modified sequentially by the increasing La content. The vibration modes in the Raman spectra show a frequency decrease with increasing doping level in $Dy_{1-x}La_xFeO_3$, which is attributed to decreasing Re-O and Fe-O force constants. The doped non-magnetic La^{3+} ions weaken the Fe-Dy interaction in $Dy_{1-x}La_xFeO_3$, which results in a decreased TSRPT and moment. The AFM temperature TN decreases due to distorted Fe-O bond lengths, which leads to weak ordering of Fe-Fe .The electron configuration of Fe^{3+} ions is found to be HS for all the samples above TN.

3) Multiferroic $Bi_{1-x}La_xFeO_3$ (x = 0.0, 0.1, 0.2, and 0.3) micro-particles by hydrothermal technique. All the samples were phase pure crystallizing in a perovskite structure with a space group of R3c. XRD refinement revealed that the lattice parameters increased along with increase of La content, while the Fe–O octahedra became more distorted. It was found that the morphologies of as-obtained micron-sized particles turned from spheroidal to octahedral according to different doping levels. The dielectric constant of $Bi_{1-x}La_xFeO_3$ sample increased after La doping, and reached the largest value for the sample of x = 0.2, both in low and high frequency range at room temperature. All the as-prepared samples exhibited magnetic moments starting above room temperature. It was found that the magnetic moment was significantly enhanced from 0.264 emu/g of $BiFeO_3$ to 0.658 emu/g of $Bi_{0.9}La_{0.1}FeO_3$ in a field of 3 T at 77 K. Both enhancements of ferromagnetic and dielectric properties possibly attribute to the changes of lattice parameters and Fe–O bond lengths caused by lanthanum substitution.

4) Perovskite solid solution ceramics with compositions of $0.9Pb(Fe_{0.5}Nb_{0.5})O_3{\cdot}0.1PbTiO_3$, $0.6Pb(Ni_{1/3}Nb_{2/3})O_3{\cdot}0.4PbTiO_3$, and $0.6Pb(Co_{1/3}Nb_{2/3})O_3{\cdot}0.4PbTiO_3$. Ferroelectric measurements revealed that these samples have well saturated polarization-electrical field loops. Dielectric measurements showed that abnormal dielectric peaks at their Curie temperature were frequency dependent. Both characteristics indicate that these samples are relaxor type ferroelectric materials. Field cooled and zero field cooled magnetization measurements revealed that the $0.6Pb(Ni_{1/3}Nb_{2/3})O_3{\cdot}0.4PbTiO_3$ and $0.6Pb(Co_{1/3}Nb_{2/3})O_3{\cdot}0.4PbTiO_3$ samples are paramagnetic down to 5 K, while the $0.9Pb(Fe_{0.5}Nb_{0.5})O_3{\cdot}0.1PbTiO_3$ sample shows an antiferromagnetic-like ordering starting from around 40 K. Furthermore, a weak ferromagnetism is observed in the $0.9Pb(Fe_{0.5}Nb_{0.5})O_3{\cdot}_{0.1}PbTiO_3$ sample, as evidenced by the magnetic hysteresis loop measured at 10 K. The AC susceptibility measurement of this sample showed that the peak position around 40 K is

strongly dependent on frequency, indicating a glassy or relaxor-type behaviour below that temperature. Therefore, relaxor type ferroelectric and magnetic $0.9Pb(Fe_{0.5}Nb_{0.5})O_3 \cdot 0.1PbTiO_3$ is a magnetoelectric relaxor.

Related publications by CI: (1) Y. Du et al, *Journal of Applied Physics*. (Accepted on 6/1/2010). (2) Z. X. Cheng, X.L. Wang et al, *Journal of Applied Physics* (Accepted on 1/3/2010). (3) Y. Du et al, *Journal of Alloys and Compounds* **490**, 637 (2010). (4) Z. X. Cheng et al, *Journal of Applied Physics* **105**, 07D902 (2009).

Better emitters, enhanced optics, superior detectors: advancing terahertz science and technology for applications in medicine, agriculture, industry and national security

Funded: 2009 2010 2011
Project ID: DP0984200
Chief Investigators: R. A. Lewis, J. Horvat, W. Xu

Progress made in 2009

Personnel W. Xu left the ANU to take up a Professorial appointment in China. Not eligible to be a CI, he has changed role to PI with ARC approval. Elise Pogson has begun a PhD on the project, supported by the student stipend requested in the grant. Colin Bleasdale has also contributed to the research; he is a PhD student funded by an APA. UOW electrical (T. Braddock), electronic (P. Ihnat) and mechanical workshop (R. Marshall *et al*.) technical staff also contributed to the project.

Equipment A major equipment failure of the Coherent pump laser of the Terahertz (THz) time-domain spectroscopy (TDS) spectroscopy system lost much time in the second half of the year. After exploring options from Coherent, SpectraPhysics, and LaserQuantum, a Millennia pump laser was finally installed in December 2009. The lost experimental time has delayed parts of the project.

Progress Candidate THz materials, sourced from the University of Nottingham, UK, and the Technical University of Darmstadt, Germany, were studied. Much experimental data was collected, analysed and prepared for publication. Seven journal papers were published in high-impact journals such as *Applied Physics Letters* and *Physical Review B*, as well as three refereed conference papers.

Development of inorganic-conducting polymer composites and ionic liquid based electrolytes for rechargeable lithium batteries

Funded: 2009 2010 2011
Project ID: DP0987805
Chief Investigators: J. Z. Wang

Progress made in 2009

1) Effects of polypyrrole on the performance of nickel oxide anode materials for rechargeable lithium-ion batteries. Nickel oxide-polypyrrole composites were prepared by a chemical polymerization method with sodium *p*-toluenesulfonate as the dopant, Triton-X as the surfactant, and $FeCl_3$ as the oxidant. Nanosize conducting polypyrrole particles were uniformly coated onto the surface of the NiO powder. The electrochemical results were improved for the NiO-PPy composite compared to the pristine NiO. After 30 cycles, the capacities of the NiO and the NiO-PPy composite were about 119 and 436 mAh g^{-1}, respectively, indicating that the electrochemical performance was significantly improved.

2) A facile route to carbon-coated SnO_2 nanoparticles combined with a new binder for Li-ion rechargeable batteries. Carbon-coated SnO_2 nanoparticles were prepared by a novel facile route using commercial SnO_2 nanoparticles treated with concentrated sulphuric acid in the presence of sucrose at room temperature. The electrochemical measurements showed that the carbon-coated SnO_2 nanoparticles with 10 % carbon and using carboxymethyl cellulose (CMC)as a binder displayed the best electrochemical performance with the highest specific capacity of 502 mAh g^{-1} after 50 cycles at a current density of 100 mA g^{-1}.

3) Self-oriented $Ca_3Co_4O_9$ thin film for enhanced cycling stability of lithium ion batteries. Self-oriented $Ca_3Co_4O_9$ nanoflake thin film has been prepared by a simple sol-gel method as the anode for thin film

lithium ion batteries. The x-ray diffraction results show that the prepared $Ca_3Co_4O_9$/Pt film is *c*-axis self-oriented and composed of nanoflakes approximately 2 μm in diameter and 200-300 nm in thickness. The reversible lithium storage capacity of the $Ca_3Co_4O_9$ thin film electrode at 1C is around 800 mAh g^{-1}, and it retains more than 70% capacity after 50 cycles.

4) Spray pyrolyzed NiO-C nanocomposite anode materials for the lithium-ion battery. Nanocrystalline NiO powders were synthesized by a spray pyrolysis method, while NiO-C nanocomposite was prepared by mixing the initial solution of nickel nitrate hexahydrate with citric acid. The capacities after 50 cycles were maintained at 141 mAh g^{-1} and 382 mAh g^{-1} for the NiO and NiO-C materials. Better electrochemical performance of the NiO-C nanocomposites could be mainly attributed to the high distribution of nano-NiO particles surrounded by carbon and the good interface affinity between the oxide and carbon particles, which prevented the active materials (NiO) from being electrically disconnected and increased their structural stability during cycling.

Publications

1. S. L. Chou, J. Z. Wang, C. Zhong, M. M. Rahman, H. K. Liu, and S. X. Dou, "A facile route to carbon-coated SnO_2 nanoparticles combined with a new binder for enhanced cyclability of Li-ion rechargeable batteries", *Electrochimica Acta* **54**, 7519 (2009).
2. X. B. Zhu, S. L. Chou, L. Wang, Q. Li, D. Q. Shi, J. Z. Wang, Z. Xin, Y. P. Sun, H. K. Liu, and S. X. Dou, "Self-Oriented $Ca_3Co_4O_9$ thin film as an anode material for enhanced cycling stability of lithium-ion batteries", *Electrochemical and Solid-State Letters* **12**, A176 (2009).
3. M. M. Rahman, S. L. Chou, C. Zhong, J. Z. Wang, D. Wexler, and H. K. Liu, "Spray pyrolyzed NiO–C nanocomposite as an anode material for the lithium-ion battery with enhanced capacity retention", *Solid State Ionics* **180**, 1646 (2010).

Linkage Projects

Development of high performance second generation superconductors

Funded: 2006 2007 2008 2009
Project ID: LP0669456
Chief Investigators: S. X. Dou, A. V. Pan, D. Q. Shi
Partner Investigators: R. Taylor, T. Yamashita, J. Barry

Progress made in 2009

The research has proceeded as planned and some significant results have been achieved as described below:

1) Doped YBCO film for coated conductors. YBCO films with Zr doping have been prepared successfully by the TFA-MOD method through dissolving Zr acetylacetonate in the precursor solution. Yttrium-stabilized zirconia (YSZ) nanoparticles were detected in the doped YBCO films by x-ray diffraction and scanning electron microscopy. A very significant enhancement of critical current density (Jc) is displayed as compared to the un-doped film at high applied fields. A high J_c near 106 A/cm^2 at 1 T and a J_c of 105 A/cm^2 at 5 T were observed in 6% doped Zr film, which are 5 times and 25 times the J_c values of the un-doped film in the same applied fields, respectively, indicating an optimal defect density created by 6% Zr doping.

The application of YBCO demands to obtain high critical current density simultaneously using cost-competitive, easily scalable preparation route. Besides Zr doped film, YBCO films with Ti doping have been prepared successfully by the low-cost trifluoroacetate metal–organic deposition method through introducing Ti butoxide in the precursor solution. Coherent hexagonal $BaTiO_3$ second phase was detected in the doped YBCO films, which leads to better connectivity, denser nanoscaled particles, and a sort of special columnar structure since gathering of planar defects. These microstructures induce significant enhancement of critical current density, especially in self-field area.

2) Deposition YBCO film on large area single crystal substrate for microwave applications. We successfully deposited double-side large area YBCO films using the trifluoroacetate metal–organic

deposition (TFA-MOD) method for microwave application. The surface resistance (R_s) of 20x20mm^2 YBCO/$LaAlO_3$ (LAO) was 4.1 at 1 GHz. The R_s of re-oxygenated YBCO/LAO (30x30mm^2) is 3.6 μOhm at 1GHz that is similar to the Theva sample which is deposited by vacuum method. In order to improve the non-linear microwave power performance, besides pure YBCO film, we have deposited (Y,Dy)123 film on $LaAlO_3$ substrate for 20 x 20 mm^2 and 30 x 30mm^2 substrates, and refined process to improve Jc, Rs and film uniformity. The best superconductivity has been obtained for the $Y_{0.6}Dy_{0.4}$BCO/LAO (30x30mm^2) with J_c ~ 5MA/cm^2 (77K, self-field), 7.0 micro ohm at 1GHz. According to the demand from the industrial partner, we have deposited YBCO film on CeO_2 buffered YSZ for 20 x 20 mm^2 and 30 x 30mm^2 substrates. Refined YBCO MOD process on CeO_2 buffered YSZ to improve J_c, R_s and film uniformity. The R_s of YBCO/CeO_2/YSZ (30x30mm^2) was 7.2 μOhm at 1GHz.

Publications

1. L. Wang, D. Q. Shi, X. B. Zhu, Q. Li, T. Yamashita, R. Taylor, J. Barry, and S.X. Dou, "Ethanol-based TFA-MOD method for preparation of YBCO films", *Physica C* (accepted 21st Oct. 2009).
2. Q. Li, D. Q. Shi, X. B. Zhu, L. Wang, T. Yamashita, R. Taylor, J. Barry, and S.X. Dou, "Preparation of YBCO film for microwave filter using a hybrid route", *Physica C* (accepted 24th Oct. 2009).
3. D. Q. Shi, L. Wang, J. H. Kim, X. B. Zhu, M. Liu, Q. Li, R. Zeng, J. Ahn, S. X. Dou, J. Yoo, Y. K. Kim, T. Yamashita, J. Barry, and R. Taylor, "YBCO film with Sm addition using low- fluorine TFA-MOD approach", *IEEE Transactions on Applied Superconductivity* **19**, 3208 (2009).
4. M. Liu, D. Q. Shi, H. L. Suo, S. Ye, Y. Zhao, Y. G. Zhu, Q. Li, L. Wang, J. H. Ahn, and M. L. Zhou, "A simple MOD method to grow a single buffer layer of $Ce_{0.8}Gd_{0.2}O_{1.9}$ (CGO) for coated conductors", *Physica C* **469**, 230 (2009).
5. M. Liu, D. Q. Shi, Q. Li, L. Wang, S. Ye, H. L. Suo, and S. X. Dou, "YBCO films with SZO doping grown by chemical solution deposition", *International Journal of Modern Physics B* **23**, 3532 (2009).

Exploration of new catalyst materials for hydrogen/air fed proton exchange membrane fuel cells

Funded: 2007 2008 2009
Project ID: LP0775109

Chief Investigators: G. X. Wang, H. K. Liu, K. Konstantinov, J. Z. Wang, D. Wexler
Partner Investigators: O. Savadogo

Progress made in 2009

The research project proceeded well as planned. Major findings are stated below.

1) Double-walled carbon nanotubes (DWCNTs) were modified for enhanced hydrogen storage by employing a combination of two techniques: KOH activation for the formation of defects on DWCNT surfaces and loading of the DWCNTs with nanocrystalline Pd. The amount of hydrogen storage capacities were measured at ambient temperature as 1.7, 2.0, 3.7, and 2.8wt% for pristine DWCNTS, 2wt%Pd DWCNTs, activated DWCNTs, and 2wt%Pd activated DWCNTs, respectively. Hydrogen molecules could be adsorbed on defect sites created by chemical activation in DWCNTs through van der Waals forces. For Pd nanoparticle loaded DWCNTs, H_2 molecules could be dissociated into hydrogen atoms and spill over to the defect sites. We found that the hydrogen storage capacity of DWCNTs can be significantly enhanced by chemical activation or loading with Pd nanoparticles.

2) Mechanical properties of single-walled carbon nanotubes (SWCNTs) with various radiuses under tensile, compressive and lateral loads are considered. Using molecular dynamic simulation (MDS) method, it can be explained that SWCNTs have higher Young's modulus and tensile stiffness than compressive elastic modulus and compressive elastic modulus and compressive stiffness. Critical axial force of zigzag SWCNT is independent from the radius, but that of armchair type rises by increasing of radius, also these two types show different buckling modes.

3) Ni@Pt core-shell nanoparticles were synthesized by chemical reduction and sequential chemical deposition. The as-prepared nanoparticles were characterized by X-ray diffraction and high resolution transmission electron microscopy. Cyclic voltammetry and steady-state polarization measurements revealed that the Ni@Pt core-shell nanoparticles have much higher catalytic activity towards oxygen reduction than that of commercial BASF 20 wt Pt% catalyst. Ni@Pt core-shell nanoparticles only

contain 16.7 atomic Pt%, therefore having a significantly reduced cost. Core-shell nanostructures could be a promising strategy to reduce the catalyst costs, but still maintain high catalytic reactivity.

4)Using molecular dynamic simulation, effects of chirality and Van der Waals interaction on Young's modulus, elastic compressive modulus, bending, tensile and compressive stiffness, and critical axial force of double-walled carbon nanotube (DWCNT) and its inner and outer tubes are considered. Achieving the highest safety factor, mechanical properties have been investigated under applied load on both inner and outer tubes simultaneously and on each one of them separately. Results indicate that as a compressive element, DWCNT is more beneficial than SWCNT since it carries two times higher compression before buckling. Except critical axial pressure and tensile stiffness, in other parameters zigzag DWCNT shows higher amounts than armchair type. Outer tube has lower strength than inner tube; therefore, the most reliable design of nanostructures can be attained if the mechanical properties of outer tube taken as the properties of DWCNT.

Publications

1. A. R. Ranjbartoreh, G. X. Wang, "Molecular dynamic investigation of mechanical properties of armchair and zigzag double walled carbon nanotubes under various loading conditions", *Physics Letters A: General, Atomic and Solid State Physics* **374**, 969 (2010).
2. A. R. Ranjbartoreh, G. X. Wang, "Consideration of mechanical properties of single-walled carbon nanotubes under various loading conditions", *Journal of Nanoparticle Research* **12**, 537 (2010).
3. H. Wu, D. Wexler, G. X. Wang, "Pt_xNi alloy nanoparticles as cathode catalyst for PEM fuel cells with enhanced catalytic activity", *Journal of Alloys and Compounds* **488**, 195 (2010).
4. G. X. Wang, H. Wu, H. K. Liu, D. Wexler, O. Savadogo, "Ni@Pt core-shell nanoparticles with enhanced catalytic activity for oxygen reduction reaction" (*in preparation*).

Miniature lithium ion battery for implantable medical device applications

Funded: 2007 2008 2009
Project ID: LP0775456

Chief Investigators: Z. P. Guo, H. K. Liu, J. Z. Wang, K. Konstantinov, M. Forsyth

Progress made in 2009

1) $LiFePO_4$/C and $LiFe_{1-x}Ni_xPO_4$/C (x = 0, 0.02, 0.04, and 0.06) composites were prepared using solid-state reaction. The as-prepared $LiFe_{1-x}Ni_xPO_4$/C composites exhibit high capacities and good cycling performance. The reason why the $LiFe_{1-x}Ni_xPO_4$/C composites have better electrochemical performance compared to the $LiFePO_4$/C composites is because nickel doping enhances the P-O bond, stabilizes the structure, and thus the charge-transfer resistance and cathode particle resistance of the composites are decreased.

2) A nanocomposite material (SnO_2-Co_3O_4) has been synthesized as an anode material for lithium-ion batteries by the molten salt method. Characterization by X-ray diffraction (XRD) and transmission electron microscopy (TEM) showed that the composite has a small particle size. The electrochemical performance was examined, including the charge-discharge and cycling properties. The experimental results showed that the sample containing the highest amount of Co_3O_4 compound exhibited a specific capacity of 355 mAh g^{-1} after 40 cycles, with cycling at 70 mA g^{-1} (35.2% higher than for the sample containing a lower amount of Co_3O_4). It seems that increasing the amount of Co_3O_4 can give good capacity retention and high specific capacity.

3) Nanostructured $LiAl_xMn_{2-x}O_{4-y}Br_y$ particles were synthesized successfully by annealing the mixed precursors, which were prepared by room-temperature solid-state coordination method using lithium acetate, manganese acetate, lithium bromide, aluminum nitrate, citric acid, and polyethylene glycol 400 as starting materials. X-ray diffractometer patterns indicated that the particles of the as-synthesized samples are well-crystallized pure spinel phase. Transmission electron microscopy images showed that the $LiAl_xMn_{2-x}O_{4-y}Br_y$ samples consist of small-sized nanoparticles. The results of galvanostatic cycling tests revealed that the initial discharge capacity of $LiAl_{0.05}Mn_{1.95}O_{3.95}Br_{0.05}$ is 119 mAh g^{-1}; after the 100^{th} cycle, its discharge capacity still remains at 92 mAh g^{-1}. The introduction of Al and Br in $LiMn_2O_4$ bring a synergetic effect and is quite effective in increasing the capacity and elevating cycling performance.

4) Novel nickel-cobalt oxides/carbon nanoflakes with Ni/Co molar ratio = 1:1 and 1:2 have been synthesized by a convenient hydrothermal method followed by a simple calcination process. X-ray diffraction results showed that the composites were composed of NiO, Co_3O_4, and carbon. Scanning electron microscope measurements demonstrated that the composites were flakes less than 100 nm in thickness, and the corresponding energy dispersive spectroscopy mapping showed that the carbon was distributed homogeneously in the composites. The electrochemical results showed that the composite electrodes exhibited low initial coulombic efficiency and excellent charge-discharge cycling stability. Additionally, the effect of different Ni/Co molar ratios on the electrochemical properties of the composites was investigated, and better performance was obtained for the sample with a Ni/Co molar ratio of 1:2.

Publications

1. N. Yanna, P. Zhang, Z. P. Guo, H. K. Liu, J. Yang, "Nickel-cobalt oxides/carbon nanoflakes as anode materials for lithium-ion batteries", *Materials Research Bulletin* **44**, 140 (2009).
2. M. F. Hassan, Z. P. Guo, Z. X. Chen, H. K. Liu, "Synthesis and characterization of carbon-coated MoO_3 composite as anode material and their applications in lithium ion batteries", *Journal of Power Sources* **195**, 2372 (2010).
3. M. H. Hassan, Z. P. Guo, H. K. Liu, "Preparation of tin nanocomposite as anode material by a molten salts method and its application in lithium ion batteries", *Physica Status Solidi (a)* **206**, 2546 (2009).
4. Y. Lu, J. Shi, Z. P. Guo, Q. S. TONG, W. J. Huang, B. Li, "Synthesis of $LiFe_{1-x}Ni_xPO_4$/C composites and their electrochemical performance", *Journal of Power Sources* **194**, 786 (2009).
5. Y. D. Huang, R. R. Jiang, S. J. Bao, D. Z. Jia, Z. P. Guo, "Synthesis and electrochemical properties of nanostructured $LiAl_xMn_{2-x}O_{4-y}Br_y$ particles", *Journal of Solid-State Electrochemistry* **13**, 799 (2009).

Development of superconducting leads with ultra-low thermal conductivity for cryoelectronic applications

Funded: 2008 2009 2010
Project ID: LP0882832
Chief Investigators: A. V. Pan, S. X. Dou
Partner Investigator: O. Mukhanov

Progress made in 2009

The project aim is to develop novel technologies for new superconducting current leads, carrying large channels of digital information with minor attenuation and ultra-low thermal conductivity for high-sensitivity, low-noise superconductive cryogenic electronics. The successful outcome will be the realisation of multi-line heat-switches based on multilayer thin/thick-film techniques, which would minimise heat generation and its transfer to cryoelectronic components.

Absolutely novel and unique design and functionality of the moving heater in the pulsed laser deposition chamber capable of moving around the laser plume, as well as ion gun incorporation allowing YBCO film deposition on nearly any (flexible) substrate by means of ion beam assisted deposition (IBAD) are designed and performed.

Thin YBCO films up to 10 cm long on various substrates have been deposited with the Tc of about 88 K along the film length. The deviation in the transition temperature is of about 2-5K maximum. The critical current density is measured on small samples cut from the long piece and achieves $1\text{-}2\times10^{10}$ A/m^2 at 77 K, which is of the level of the best short film samples. It is expected that the long length films have this current density of the entire length. New low temperature experimental setup is currently being developed and the long film transport properties are currently being tested.

Optimizing the properties of flexible YBCO films the following work has been carried out.

Different materials were tested to create the simplified buffered structure on top of ISD-MgO templates. STO buffer layer has been verified as the best candidate to be deposited between YBCO and ISD-MgO template because of its nearly perfect matching with YBCO and MgO.

The quality superconducting (Y/Nd)BaCuO multilayered film structures have been grown by pulsed laser deposition on metallic substrates with an incline substrate deposited magnesium oxide buffer layer.

The magneto-optical imaging shows developed granular structure with flux penetration along the grain boundaries. The size of the grains is similar to the grain size of underlying metallic substrates. SEM observation confirms that YBCO films deposited on top of CeO_2 and STO thin buffer layers possess best surface topography. The enhancement of the critical current density has been observed in multilayers compared with the same thickness of monolayer structures. The origin of this *Jc* increase is in improved microstructure of the multilayered systems obtained. The two networks of grains, one in metal substrates and the other in superconducting films, are the factors contributing to the limitation of supercurrent flow. At the same time the extensive disorder compared to the films on single crystal substrates grain enables stronger pinning properties and higher Jc values. Generally, multilayering plays its positive role in creation less porous and ordered columnar-like structure during deposition process.

The day-to-day progress report is discussed and adjusted on monthly meetings with the industry partners.

Publications

Refereed journal papers:

1. S. V. Pysarenko, A. V. Pan, S. Downing, S. X. Dou, "Development of multilayer coated conductors with simplified buffer structure", *International Journal of Modern Physics B* **23**, 3526 (2009).
2. O. V. Shcherbakova, A. V. Pan, S. X. Dou, R. Nigam and D. Wexler, *Journal of Applied Physics*, accepted on 17/02/2010, *in press.*

Conference presentations:

1. A. V. Pan, S. V. Pysarenko, O. V. Shcherbakova, S. X. Dou, "On YBaCuO superconducting films, multilayers and pinning mechanism", EUCAS-2009, 13-17 September, 2009, Dresden, Germany.
2. A. V. Pan, "YBCO superconducting thin films", First Joint UOW/CSIRO Workshop on Advanced Materials: Superconductors, 26 August 2009, Innovation Campus, Fairy Meadow, Australia.

Novel methods for enhancing room temperature ZT of thermoelectric/thermionic materials

Funded: 2008 2009 2010
Project ID: LP0882282

Chief Investigators: C. Zhang, X. L. Wang, G. X. Wang
Partner Investigator: T. Toyoda

Progress made in 2009

We continued simulation work on the thermal transport in nanostructured materials. We examined the effect of electrodes' dimensionality geometry on the overall electron efficient of layer semiconductor thermionic devices.

We have carried out the first experiment in the world to dope the newly discovered graphene into the Bi_2Te_3 thermoelectric materials. The electronic structure and thermoelectric properties of Bi_2Te_3 single crystals and graphene-doped Bi_2Te_3 polycrystalline samples were investigated with the aid of first-principles calculations, X-ray diffraction, scanning electron microscopy, Rietveld refinement, and thermal and transport measurements. It was found that the p electrons from the Bi and Te atoms are responsible for the density of states near the Fermi level. Experimental results show that the graphene-doped Bi_2Te_3 exhibits lower thermal conductivity and has higher figure of merit than the single crystals. This work has been accepted for publication in "Thin solid films"

The newly discovered Fe-based superconductor shows a good thermoelectric property at low temperature. We studied for the first time the crystal structure, electronic, and thermal properties of a high-quality polycrystalline $TbFeAsO_{0.85}$ sample made by a high pressure technique are investigated. We found that this compound exhibits a relative large thermal power or Seebeck coefficient. This work has been published in Applied Physics Letters.

Publications

1. M. F. O'Dwyer, T. E. Humphrey, R. A. Lewis, C. Zhang, "Efficiency in nanometre gap vacuum thermionic refrigerators", *Journal of Physics D: Applied Physics* **42**, 035417 (2009).

2. A. R. Wright, J. F. Liu, Z. S. Ma, Z. Zeng, W. Xu and C. Zhang, "Thermodynamic properties of graphene nanoribbons under zero and quantizing magnetic fields", *Microelectronics Journal* **40**, 716 (2009).

Development of advanced lithium ion battery and battery management system for electric/hybrid electric vehicle applications

Funded: 2009 2010 2011
Project ID: LP0991012
Chief Investigators: Z. P. Guo, H. K. Liu, C. D. Cook, D. Wexler
Partner Investigator: H. Zhu, X. J. Zhu

The project was funded in the second round 2009. We are currently finalizing the agreement with the partner organizations. The project will commence by the end of June, 2010.

Magnesium diboride superconductor magnets for applications

Funded: 2009 2010 2011
Project ID: LP0989352
Chief Investigators: S. X. Dou, X. L. Wang, C. D. Cook, X. Xu
Partner Investigator: E. W. Collings, J. Yoo

Progress made in 2009

The project will focus on the development of superconducting magnesium diboride magnets for applications such as magnetic separation and magnetic resonance imaging. To achieve these goals the objectives of the proposal will be: (i) to translate the novel technologies which have already been demonstrated in wire samples and bulk objects to scalable technologies, (ii) to develop superconducting joints that will enable magnet operation in the persistent mode, (iii) to improve thermal and electrical stability, essential for the operation of magnet-grade conductors, (iv) to design, build, and test solenoid magnets for applications.

1. Research to find maximum Jc with three sources of boron, China (Tangshang, BaoDing) and SMI. From this work we will establish the boron source to use for future use on researching further dopants or wire processing innovations.

2. Determine the appropriate ratio of Mg/B for optimization with the optimum % of malic acid.

3. Optimization of Carbon doped Boron (low level) from SMI with an additive- graphene.

Publications

1. X. Xu, J. H. Kim, S. X. Dou, S. Choi, J. H. Lee, H. W. Park, M. Rindfleisch and M. Tomsic, "A correlation between transport current density and grain connectivity in MgB_2/Fe wire made from ball-milled boron", *Journal of Applied Physics* **105**, 103913 (2009)
2. X. Xu, J. H. Kim, Y. Zhang, M. Jercinovic, and E. Babic, "Critical current density performance of malic acid doped magnesium diboride wires at different operating temperatures", *International Journal of Modern Physics B* **23**, 3497 (2009).
3. X. Xu, J. H. Kim, Y. Zhang, Y. Zhao, M. Rindfleisch, and M. Tomsic, "Superconducting properties of MgB_2 wire using ball-milled low purity boron", *IEEE Transactions on Applied Superconductivity* **19**, 2714 (2009)

Novel lithium iron based olivine phosphates as cathode materials for the development of new generation power batteries

Funded: 2009 2010 2011
Project ID: LP0989134
Chief Investigators: G. X. Wang, D. Wexler, J. Horvat, C. Zhang
Partner Investigator: H. Kim

Progress made in 2009

This research project was started on November 2009. It has been delayed due to long time negotiation with two industry partners and late recruitment of APAI PhD student. However, we still carried out some preliminary investigations in 2009.

Nanolayer carbon coating is an effective approach to improve the electronic conductivity of $LiFePO_4$ cathode materials. In this paper, pristine and carbon-coated $LiFePO_4$ were synthesized by solid state reaction. The as-prepared carbon-coated $LiFePO_4$ nanoparticles have a homogeneous nanolayer carbon coating with a thickness of 5 nm, which has been confirmed by high resolution transmission electron microscopy. The electrochemical properties of $LiFePO_4$ and nanolayer carbon coated $LiFePO_4$ electrodes were evaluated through cyclic voltammetry, electrochemical impedance spectroscopy, and galvanostatic charge-discharge testing. Lower polarization, higher rate capacity, and better cycling stability were obtained from the carbon-coated $LiFePO_4$ nanoparticles. Therefore, nanolayer carbon coated $LiFePO_4$ cathode materials could be widely used in large-scale lithium ion batteries for high power application such as static energy storage and electric vehicles.

International Linkage Award Projects

Advanced materials and structures for terahertz science and technology

Project ID: LX0776043
Funded: 2007 2008 2009
Chief Investigators: R. A. Lewis, R. Mendis, R. E. M. Vickers
Partner Investigators: H. L. Hartnagel, C. Sydlo

Progress made in 2009

Fruitful exchange visits took place with Prof. Lewis (Wollongong) visiting Darmstadt and Prof. Hartnagel (Darmstadt) visiting Wollongong. PhD student Mr Schoenherr (Darmstadt) visited Wollongong for a period of a month to conduct experiments on Schottky detectors over a large wavelength range using the Fourier-transform spectrometers at UOW

Development of nano-structured thermoelectric materials for power generation from heat

Project ID: LX0881969
Funded: 2008 2009 2010
Chief Investigators: S. X. Dou, Y. Zhao, G. Peleckis
Partner Investigators: X. X. Xi, G. Ramanath, Q. J. Li

Progress made in 2009

On of the key aims of this project is to bring together three world-renowned groups in materials engineering, solid state physics, and thin film technology, to investigate completely new types of thermoelectric heterostructures to enable the development of novel thermal-energy harvesting electric power generation devices. Extensive sharing in theoretical knowledge, sample preparation and analysis techniques, as well as ideas for prototype device construction is essential for development and investigation of brand new thermoelectric structures and assemblies. Arranged inter-institutional visits of researchers and postgraduate students are necessary for strong and effective collaboration, as well as to strengthen the links between Australian and USA research institutions.

In the second year of the project, the main focus of the research was to establish synthesis techniques for preparation of nano-structured oxide thermoelectric materials. Due to the significant degradation of semiconductor based thermoelectrics, oxide materials are the only good candidates for thermoelectric conversion at high temperatures in air. The main compound we have investigated was Ca-Co-O system, the so called Ca-349 phase. We have applied wet chemistry approach to fabricate nano-structured Ca-

349 phase, which would yield in decreased thermal conductivity due to the increased phonon scattering. Our results showed, that introduction of a polymer based material as surfactant works very well to decrease particle size to around 60-80 nm. The morphology of the materials has been found to be very uniform and results are very much reproducible. The thermoelectric properties measured showed slight decrease in thermal conductivity, however, electrical resistivity of the prepared samples increased, as compared to samples prepared by standard solid state synthesis technique. This might be caused by presence of impurities, originating from the leftovers of surfactant. We have also investigated the particle size evolution as a function of time. We found that during sintering of the sample in the final stage, the crystallites are formed within first hour, which identified the reasons why crystallite size in long time sintered time is usually very large. The aggregation and joining of the crystallites takes place around 3rd hour of the synthesis. This caused increased thermal conductivity, as there is significant decrease in grain boundaries, which act as phonon scatterers.

With collaborators from Rensselaer Polytechnic Institute we have investigated ways to prepare nano-structured ZnO by using wet chemistry and microwave synthesis techniques. We were successful in fabricating such nanostructures. The applied microwave synthesis technique is very efficient and very fast. Samples can be obtained just after 5 to 10 minutes of microwave exposure. Obtained nano particles are well formed and have highly pronounced hexagonal shape, which correlates to the crystal structure of ZnO very well.

Mechanism and enhancement of supercurrent carrying ability in magnesium diboride superconductor

Project ID: LX0882225
Funded: 2008 2009 2010
Chief Investigators: X. L. Wang
Partner Investigators: S. I. Lee

Progress made in 2009

1) Flux pinning study of MgB_2 superconductors. The transport and magnetic properties of 10 wt % malic acid and 5 wt % nano-carbon doped MgB_2 have been studied by measuring the resistivity (ρ), critical current density (*Jc*), connectivity factor (*AF*) irreversibility field (*H*irr), and upper critical field (*H*c2). The pinning mechanisms are studied in terms of the collective pinning model. It was found that both mean free path (δl) and critical temperature (δTc) pinning mechanisms coexist in both doped MgB_2. For both the malic acid and nano-carbon doped samples, the temperature dependence of the crossover field which separates the single vortex and the small bundle pinning regime, *Bsb*(*T*), shows that the δl pinning mechanism is dominant for temperatures up to t (T/Tc) = 0.7, but the δTc pinning mechanism is dominant for $t > 0.7$. This tendency of coexistence of the δl and the δTc pinning mechanism is in strong contrast with the pure MgB_2, in which the δTc pinning mechanism is dominant over a wide temperature range below *Tc*. It was also observed that the connectivity factor, active cross-sectional area fraction (*AF*), are 0.11 and 0.14 for the nano-carbon and the malic acid doped MgB_2, respectively, indicating that there is still room for further improving Jc performance. A joint paper entitled "Strong competition between the δl and δTc flux pinning mechanisms in MgB_2 doped with carbon containing compounds" has been accepted for publication and is now in press in *Journal of Applied Physics.*

2) Magnetic study of a newly discovered Fe-based superconductor. We present reversible magnetization measurements for applied fields in the range from 0.5 to 7 T made while varying the temperature for optimally doped $BaFe_{1.8}Co_{0.2}As_2$ single crystals with *T*c = 23.6 K. The rounding fluctuating magnetization was observed in the reversible range of magnetization for temperatures above 18 K. This fluctuation effect is quite small compared with that in high temperature cuprate superconductors, but is still large enough for obtaining the essence of the physical properties in this iron pnictide superconductor. This reversible magnetic fluctuation follows a three-dimensional scaling form in the critical fluctuation region for fields above 0.5 T, which indicates that this iron pnictide superconductor belongs to the class of three-dimensional superconductors. A joint paper on "The fluctuation effect of $BaFe_{1.8}Co_{0.2}As_2$ single crystals from reversible magnetization" has been published in *Superconductor Science & Technology* **22**, 105016 (2009).

3) Magnetic-transport properties of a Fe-based superconducting single crystal. The magneto-fluctuation conductivity, called excess conductivity, originated from the forming of the superconducting droplet near to the mean field transition temperature, was measured for the optimally doped $BaFe_{1.8}Co_{0.2}As_2$ single crystals with a critical temperature, Tc, of 24.6 K. This measurement of the excess conductivity for magnetic fields up to 9 Tesla was compared with the thermodynamic scaling theory in the critical region, in which not only the Gaussian fluctuation but also fourth order terms of the order parameter are included. An analysis of the excess conductivity showed that the superconductivity followed three-dimensional scaling rather than two-dimensional scaling even though the sample had a layered structure. This work has been under review with *Journal of Applied Physics.*

Magnetic walls as nano-manipulators for physics, bio- and medical technologies

Project ID: LX0990073
Year Funded: 2009
Chief Investigators: A. V. Pan, T. Johansen
Fellowship Awarded: T. Johansen

Progress made in 2009

The work carried out has addressed both experimental and theoretical aspects. In particular, using

- magneto-optical imaging, allowing direct observation of domain wall motion in ferromagnetic films with strong Faraday effect, together with
- conventional magnetometry (isothermal M-H curve measurements) and
- SEM characterization of the films.

We have obtained new experimental results that allow direct quantitative comparison with theoretical predictions. For the first time, M-H curves could be compared with an *exact analytical calculation* of the domain wall behaviour. Our experimental results confirm the model calculations with excellent accuracy near the critical point where the period of the stripe pattern diverges.

In fact, these achievements form a new basis for continued work on stripe domain behaviour in magnetic films, including multilayered films with ferromagnetic and/or antiferromagnetic interactions. Moreover, the work is also extendable in the direction of fundamental research on so-called modulated systems. This highly diverse class of physical systems include quasi-2D systems made from ferrofluids, type-I superconductors and more, all demonstrating that their energy is minimized by forming stripe-shaped domains in a similar manner as in the ferrite garnet films studied in the present project.

Publications

1. P. Tierno, F. Sagues, T. H. Johansen and Th. M. Fischer, "Colloidal transport on magnetic garnet films", Perspective in *Physical Chemistry Chemical Physics* **11**, 9615 (2009).
2. V. V. Yurchenko, T. H. Johansen and Y. M. Galperin, "Dendritic flux avalanches in superconducting films", *Low Temperature Physics* **35**, 789 (2009).

Invited presentations by T. H. Johansen:

1. "Magnetic walls creating colloidal micromachines", International workshop on advanced materials and their applications, Innovation Campus, Wollongong, NSW, Australia. March 19-20, 2009.
2. "Magnetic walls for nanomanipulation", University of Wollongong, Wollongong, NSW, Australia. March 26, 2009.
3. "Mobile magnetic walls as nano-manipulators", National Measurement Institute (NMI), West Linfield, NSW, Australia. April 8, 2009.
4. "Magnetic walls as nano-manipulators", Bragg Institute, Australian Nuclear Science and Technology Organisation, Menai, NSW, Australia. April 23, 2009.
5. "Mobile magnetic walls as nano-manipulators", University of New South Wales at the Australian Defence Force Academy, UNSW@ADFA, Canberra ACT, Australia. May 1, 2009.
6. "Magnetic domains and particle manipulation" Institute for Superconducting and Electronic Materials (ISEM), the University of Wollongong, Wollongong, NSW, Australia. June 4, 2009.

CSIRO Flagship Grants

"Mg-based hydrogen storage materials" and "Hydrogen storage in carbon", with National Hydrogen Materials Alliance

Funded: 2007 2008 2009
Chief Investigators: H. K. Liu
Associate Fellows: Z. P. Guo, S. Aminorroaya-Yamini
PhD Students: A. Ranjbar, C. K. Poh

Progress made in 2009

Mg-6 wt% Ni alloy was fabricated by a casting technique and the drilled chips ball-milled by high energy ball-milling to be examined for their hydrogenation modified with multi-walled carbon nanotubes (MWCNTs). The activation characteristics of ball-milled alloy are compared with those of the materials obtained by ball-milling with 5 wt% MWCNTs for 0.5, 1, 2, 5 and 10 hours. MWCNTs enhanced the absorption kinetics considerably in all cases. The hydrogen content of the modified powder with MWCNTs reached maximum hydrogen capacity within two minutes of exposure to hydrogen at 370°C and 2MPa pressure. X-ray diffraction analysis provided evidence that no carbon-containing phase was formed during milling. However, milling with MWCNTs reduced the crystallite size, even if the milling was carried out for only an hour. The rate-controlling steps of the hydriding reactions at different milling times were determined by fitting the respective kinetic equations. Evidence is provided that nucleation and growth of hydrides are accelerated drastically by a homogenous distribution of MWCNTs on the surface of the ball-milled powders. We show that MWCNTs are very effective at promoting the hydriding/dehydriding kinetics, as well as increasing the hydrogen capacity of the magnesium alloy.

Less than 1 wt% Nb added to Mg-10 wt% Ni alloy during casting to investigate the effect of inter-metallic Nb-Ni phases on hydrogenation/dehydrogenation properties of the alloy, followed by milling of various amount of metallic niobium with the alloy. We recently found that the addition of 5 wt% multi-walled carbon nanotubes (MWCNTs) to Mg-Ni alloy offers an excellent activation characteristics and leads to a pronounced improvement in the hydrogen storing properties. Therefore, 5 wt% MWCNTs added to all ball-milled samples of the present study.

We demonstrate the proof-of-principle that interaction between visible light and a magnesium hydride sample in reflective mode can be used to determine desorption temperature and kinetics of magnesium hydride in powder form. The demonstrated optical technique requires only milligrams of sample and can potentially be used to measure the de/absorption temperature and kinetics of magnesium nanostructures, which are often fabricated via the physical vapour deposition method inside an optically transparent quartz tube. This would help to eliminate the common problem of oxidation associated with removal and transport of the freshly fabricated nanostructures into an inert protective environment. This optical technique could be applied to any hydrogen storage material in the form of powder which shows a significant difference in its optical absorption between the hydride and the non-hydride phase.

Publications

1. A. Ranjbar, Z. P. Guo, X. B. Yu, D. Wexler, A. Calka, C. J. Kim, and H. K. Liu, "Hydrogen storage properties of MgH_2–SiC composites", *Materials Chemistry and Physics* **114**, 168 (2009).
2. A. Ranjbar, Z. P. Guo, X. B. Yu, D. J. Attard, A. Calka, and H. K. Liu, "Effects of SiC nanoparticles with and without Ni on the hydrogen storage properties of MgH_2", *International Journal of Hydrogen Energy* **34**, 7263 (2009).
3. H. B. Lu, C. K. Poh, L. C. Zhang, Z. P. Guo, X. B. Yu, and H.K. Liu, "Dehydrogenation characteristics of Ti- and Ni/Ti-catalyzed Mg hydrides", *Journal of Alloys and Compounds* **481**, 152 (2009).
4. C. K. Poh, Z. Guo, and H. K. Liu, "Real-time measurement of desorption temperature and kinetics of magnesium hydride powder sample based on optical reflection", *International Journal of Hydrogen Energy* **34**, 9168 (2009).

Current & Ongoing Research Projects

ARC Centre of Excellence

ARC Centre of Excellence

Nano-materials for energy storage

Years funded:	2006	2007	2008	2009	2010
Amount funded:	$230,000	$230,000	$230,000	$230,000	$230,000
Project ID:	CE0561616				
Chief Investigator:	H. K. Liu				
Research Fellow:	J. Z. Wang				
Postgraduate Students:	S. L. Chou, M. D. Rahman, C. Zhong				

ARC Discovery Projects

Exploration for new materials for spintronics

Years Funded:	2005	2006	2007	2008	2009
	$210,000	$210,000	$120,000	$120,000	$120,000
Total Funding:	$870,000				
Project ID:	DP0558753				
Chief Investigator:	X. L. Wang				

Project Summary: The scope for use of spintronic materials in practical applications will be enormous and there will be a huge market for spintronic devices. In fact, giant magnetoresistance spintronic materials are already used in practical applications such as magnetic recording and storage devices. The success of this project will certainly lead to a discovery of novel magnetic semiconductor spintronic materials and better understanding of spin dependent magnetic interactions. It will enhance the international competitiveness and export power of Australian industry in the areas of information technology, quantum computing, magnetic recording and magneto-electronics.

Current limiting mechanisms in magnesium diboride superconductors

Year Funded:	2007	2008	2009	2010	2011
	$320,000	$330,000	$390,000	$180,000	$210,000
Total Funding:	$1,430,000				
Project ID:	DP0770205				
Chief Investigators:	S. X. Dou				
Partner Investigators:	J. Driscoll, R. L. Flukiger, H. Kumakura, M. D. Sumption				

Project Summary: Numerous important applications have already been identified for MgB_2 wire: power transmission cables, fault current limiters, transformers and magnets for motors and generators, as well as MRI. The significant increase in current carrying capacity of one order of magnitude expected to result from the proposed program will enable MgB_2 to replace presently existing low-temperature superconductors (LTS) and expensive high-temperature superconductors (HTS) in numerous important applications. MgB_2 technology, coupled with renewable energy sources, has the potential to provide a long-term solution to the energy crisis and global warming threat.

First principles for development of novel hybrid electrochemical energy storage and conversion systems

Year Funded:	2007	2008	2009	2010	2011

	$210,000	$210,000	$220,000	$130,000	$130,000

Total Funding: $900,000
Project ID: DP0772999
Chief Investigators: G. X. Wang, C. Zhang, K. K. Konstantinov, J. Z. Wang,
Partner Investigators: M. S. Islam, R. S. Liu, P. Novak, P. H. Notten
Project Summary: Electrochemical energy is regarded as an alternative green energy/power source. The breakthrough technologies to be developed will allow us to realise the great goal of widespread usage of electric vehicles and hybrid electric vehicles, inducing dramatic improvements to our environment. It will also help us to reduce our dependence on the current oil-driven economy, and increase national energy security and energy independence. The project will establish indigenous expertise and scientific know-how on electrochemical energy storage and conversion technology. The competitive results from this research will provide an incentive to the Australian automobile and energy industries.

New concepts with multidisciplinary approach: novel functionalised nanostructures for hydrogen storage

Year Funded:	2007	2008	2009
	$100,000	$100,000	$100,000

Total Funding: $300,000
Project ID: DP0771193
Chief Investigators: Z. P. Guo, H. K. Liu
Partner Investigators: P. H. Notten, J. Chen, A. Zuettel
Project Summary: This project addresses National Research Priorities in the areas of breakthrough science, frontier technologies and advanced materials. Developing new methodologies to fabricate novel functionalised nanostructured materials with tailored properties has great potential in areas including energy storage, novel catalysts, novel sensors, micro/nano-electronics, etc. This project will enhance the international reputation and impact of Australian research in the internationally focused fields of nanotechnology and hydrogen energy technology. Applying innovative nanotechnology to the area of hydrogen energy will add to Australia's export potential and reduce Australia's reliance on foreign fuel sources.

Charge transfer mechanism in 3-dimensional pore-solid nanoarchitectures for electrochemical systems

Years Funded:	2008	2009	2010
	$100,000	$100,000	$100,000

Total Funding: $300,000
Project ID: DP0878611
Chief Investigator: Z. P. Guo
Project Summary: This project represents a significant scientific and economic advance for Australia because: 1) it is likely to create advanced energy storage and conversion devices, with excellent working efficiency and kinetics, which will induce dramatic improvements to our environment 2) the project will establish local expertise and scientific know-how on electrochemical energy storage and conversion systems, which will place Australia at the forefront of this important area of lithium ion battery and PEM fuel cells; 3) relevant Australian enterprises in electric vehicle and portable device manufacturing will reap the benefits of these discoveries.

Development of novel high efficiency thermoelectric oxides for high temperature power generation

Years Funded:	2008	2009	2010

	$35,000	$35,000	$35,000	
Total Funding:	$105,000			
Project ID:	DP0879714			
Chief Investigator:	G. Peleckis			

Project Summary: Thermoelectric materials are considered as a key factor in clean energy production, based on the conversion of waste heat emitted by power plants and automobiles to electricity. A series of novel high performance Co-based oxide thermoelectric materials will be developed by this project using nanotechnology and advanced material processing techniques. Significant improvement of the heat-to-electricity conversion factor is expected to result from the proposed program. The novel thermoelectric oxides with high thermoelectric performance will be practically used for high temperature power generation. This will provide a long-term solution to the global warming threat through decreasing amounts of waste heat presently generated.

Fabrication of high quality MgB_2 superconductor

Years Funded:	2008	2009	2010	
	$40,000	$40,000	$40,000	
Total Funding:	$120,000			
Project ID:	DP0879843			
Chief Investigator:	S. H. Zhou			

Project Summary: Superconductors are electrical resistance free materials. They have great potential for power applications. Nowadays, superconductors have been used in applications such as Magnetic Resonance Imaging and other R&D equipment. This project deals with newly discovered MgB_2 superconductor. The process outlined in this project will produce MgB_2 superconductor with better superconducting properties. The application of MgB_2 superconductor will save energy, and enhance the performance of existing electrical devices such as magnet and power line.

Giant magnetocaloric materials and room temperature refrigeration

Years Funded:	2008	2009	2010	2011	
	$210,000	$210,000	$120,000	$120,000	
Total Funding:	$660,000				
Project ID:	DP0879070				
Chief Investigators:	S. X. Dou; J. H. Kim				
Partner Investigators:	T. H. Johansen; E. Bruck				

Project Summary: The objectives of this project are to develop new magnetocaloric materials, study their properties and their potential as components of advanced magnetic refrigeration systems. The outcomes of this project will provide an opportunity for Australian industry to produce magnetocaloric materials and magnetic refrigeration systems with higher quality, to embark on this novel innovation technology in an effective way, and to access the international magnetic refrigeration market. In the longer term, the successful outcome of this research could lead to energy savings and an overall reduction in greenhouse gas emissions, as well as contributing to the associated economic and social goals.

Improvement and synthesis of advanced hydrogen storage materials for fuel cell applications

Years Funded:	2008	2009	2010	
	$96,000	$96,000	$96,000	
Total Funding:	$288,444			
Project ID:	DP0878661			
Chief Investigator:	X. B. Yu			

Project Summary: Energy systems of the future must be cleaner and much more efficient, flexible, and reliable to meet the growing global demand for energy. A hydrogen economy offers a

potential solution to satisfying the global energy requirements while reducing carbon dioxide and other greenhouse gas emissions and improving energy security. The enhanced hydrogen storage materials to be investigated will have higher hydrogen storage capacity, which can have applications in a variety of areas, including the storage and transport of hydrogen, fuel cells and electric automobiles.

Novel graphene nanostructures: modelling, synthesis, fabrication and characterization

Years Funded:	2008	2009	2010
	$150,000	$145,000	$145,000
Total Funding:	$440,000		
Project ID:	DP0879151		
Chief Investigators:	C. Zhang, D. Li		
Partner Investigators:	F. Liu; R. B. Kaner; Y. Jiang		

Project Summary: As a key nanomaterial for future electronics, graphene is rapidly becoming one of the most promising frontier areas of nanotechnology throughout the world. This project aims to develop a new class of graphene nanostructures that hold great potential for large-scale applications in the next generation nanoelectronic devices, sensors, solar cells and light emitting devices. This project will significantly enhance the international competitiveness of Australia in the areas of new materials and nanotechnology and will help place Australia at the forefront of nanotechnology. This project will produce high quality PhD students in nanotechnology.

Tailoring superconducting hybrid multilayered film systems for electric and electronic applications

Years Funded:	2008	2009	2010	2011	2012
	$165,000	$164,000	$159,000	$120,000	$105,000
Total Funding:	$713,000				
Project ID:	DP0879933				
Chief Investigators:	A. V. Pan;				
Partner Investigators:	C. P. Foley, T. H. Johansen; H. Hilgenkamp				

Project Summary: This project focuses on the development of new scientific and technological aspects of the fabrication, properties and operation of novel hybrid systems for revolutionizing electricity handling and electronics. It will also solve some existing problems of film structures with promising multilayer technology. Hybrid systems often make the headlines in science and are gaining an increasingly promising outlook in materials engineering, nanotechnology and electronics, promising eventual application in a broad range of industries. This project will establish Australia's capability at the forefront in this area. The outcomes predicted will benefit existing Australian companies and may establish new companies dealing with these hybrid systems.

Frustrated magnets: a new platform for multiferroic materials

Years Funded:	2009	2010	2011
	$160,000	$115,000	$115,000
Total Funding:	$390,000		
Project ID:	DP0987190		
Chief Investigators:	X. L. Wang, Z. X. Cheng, D. P. Chen;		
Partner Investigators:	T. Kimura, F. Klose		

Project Summary: Ferroelectric materials with simultaneous ferroelectricity and ferromagnetism are one of the most important new emerging fields in the materials science and condensed matter physics communities. Novel magneto-electronic devices based on new multiferroic materials will open up a huge market for these devices, which are expected to have a huge impact on modern science and

daily life. The purpose of this project is to make Australia one of the leading countries in this field and to work with colleagues inside Australia and around the world to move this field forward for mutual benefit.

Better emitters, enhanced optics, superior detectors: advancing terahertz science and technology for applications in medicine, agriculture, industry and national security

Years Funded:	2009	2010	2011
	$120,000	$90,000	$90,000
Total Funding:	$300,000		
Project ID:	DP0984200		
Chief Investigators:	R. A. Lewis, J. Horvat		
Partner Investigator:	W. Xu		

Project Summary: We will start with a new fundamental study of the interaction of light and matter to explicate the phenomena of the emission, transmission and detection of terahertz electromagnetic radiation. Using our increased understanding of terahertz science, we will the engineer better terahertz sources, optics, and sensors. Getter terahertz technology will open up new applications in medical diagnosis, especially dermatology; industrial productivity, such as quality control; and the detection of contraband, including illicit drugs and explosives. In maintaining good health, transforming industries and safeguarding Australia, advanced terahertz systems will bring the nation health, economic and security benefits.

Development of inorganic-conducting polymer composites and ionic liquid based electrolytes for rechargeable lithium batteries

Years Funded:	2009	2010	2011
	$110,000	$110,000	$110,000
Total Funding:	$330,000		
Project ID:	DP0987805		
Chief Investigators:	J. Z. Wang		

Project Summary: The project will lead to development of safe lithium batteries for electric vehicles and hybrid electric vehicles to contribute to the national priority goal of reducing and capturing emissions in transport to improve our environment. Small, flexible batteries for new implantable medical devices will also be developed to treat millions of people suffering from different diseases. The development of new scientific knowledge related to this project will place Australia at the forefront of an emerging domain of research. The projects will take the incentive in establishing a leading national position in development of new energy storage technology.

ARC Linkage Projects

Development of high performance second generation superconductors

Years funded:	2006	2007	2008	2009
Amount funded:	$115,000	$218,000	$193,000	$90,000
Total funding:	$616,000			
Project ID:	LP0669456			
Chief Investigators:	S. X. Dou, A. V. Pan, D. Q. Shi,			
Partner Investigators:	R. Taylor, J. Barry, T. Yamashita			
Industry Partners:	Mesaplexx Pty. Ltd.			

Project Summary: Robust, high performance high temperature superconductor (HTS) wire underpins a worldwide opportunity to revolutionize the electric power grid, transportation, electronics and many other industries with a new generation of high efficiency, compact, and environmentally friendly electrical equipment. This program combines our expertise in superconductor thin film fabrication and characterization and expertise of a local industrial partner in the development of superconducting wires. The success of the proposed project will bring benefit to local industry and employment, and significantly enhance the international competitiveness in HTS of Australian industry.

Exploration of new catalyst materials for hydrogen/air fed proton exchange membrane fuel cells

Years funded:	2007	2008	2009
Amount funded:	$110,000	$100,000	$90,000
Total funding:	$300,000		
Project ID:	LP0775109		
Chief Investigators:	G. X. Wang, H. K. Liu, K. K. Konstantinov, J. Z. Wang, D. Wexler		
Partner Investigators:	O. Savadogo		
Industry Partners:	Lead Power Battery Co. Ltd.		

Project Summary: Fuel cell technology is the most critical technology for the hydrogen economy. Hydrogen/air fed fuel cells can provide pollution-free power sources for vehicles and distributed power generation. A breakthrough in fuel cell technology using hydrogen as fuel will supply us with clean and sustainable energy sources, dramatically improve our environment, and maintain national energy security. The success of fuel cell technology will also significantly reduce our dependence on oil. This research project is expected to establish local expertise, and scientific and industrial know-how on fuel-cell technology.

Miniature lithium ion battery for implantable medical device applications

Years funded:	2007	2008	2009
Amount funded:	$110,000	$100,000	$100,000
Total funding:	$310,000		
Project ID:	LP0775456		
Chief Investigators:	Z. P. Guo, H. K. Liu, J. Z. Wang, K. K. Konstantinov, M. Forsyth		
Industry Partners:	DLG Battery Co. Ltd.		

Project Summary: This project addresses National Research Priorities in the areas of breakthrough science, frontier technologies and promoting and maintaining good health. Substantial national benefit could be derived from this project: (i) Australia will innovate in an important and intensely active area in which the results will have long-lasting significance in implantable rechargeable battery development; (ii)The development of new scientific knowledge related to this project will place Australia at the forefront of an emerging domain of research body batteries; (iii) In the long term, the successful outcome of this research will lead to more reliable batteries for implantable devices, thereby promoting health care.

Development of superconducting leads with ultra-low thermal conductivity for cryoelectronic applications

Year Funded:	2008	2009	2010	
	$151,000	$141,000	$146,000	
Total Funding:	$438,000			
Project ID:	LP0882832			
Chief Investigators:	A. V. Pan; S. X. Dou			
Partner Investigator:	O. Mukhanov			
Industry Partner:	Hypres Inc., Microwave & Materials Design Pty. Ltd.			

Project Summary: Superconducting systems are revolutionary technologies that have the potential to make a significant impact on society. The development of the new technology of superconducting wiring, which would effectively eliminate heat generation and its transfer to the cryogenic electronics, and its subsequent employment will enable superconductive electronics to become price competitive, significantly outperforming conventional systems. The establishment of this new frontier technology of heat-switch current leads will benefit Australian industries and have a dramatic impact in the future on the field of cryogenic quantum electronics (such as quantum computing), which is currently under profound exploration in Australia.

Novel methods for enhancing room temperature figure of merit of thermoelectric/thermionic materials for refrigeration applications

Year Funded:	2008	2009	2010	
	$81,000	$79,000	$87,000	
Total Funding:	$247,000			
Project ID:	LP0882282			
Chief Investigators:	C. Zhang; X. L. Wang; G. X. Wang;			
Partner Investigator:	T. Toyoda			
Industry Partner:	Hydrokinetics Pty. Ltd.			

Project Summary: With global warming and an increased awareness of climate change, devices such as thermoelectric modules can be part of the solution, particularly if their relative power and efficiency can be increased. The aim of this project is to bring together theoreticians, experimentalists, materials scientists, and industrial partners with complementary expertise to develop new techniques and methods for fabricating novel thermoelectric/thermionic materials with high figure of merit, ZT, for solid state refrigeration applications. The success of the project will lead to a 3 to 5 fold increase in the market share of thermoelectric cooler and will have a significant impact on the Australian economy and reduce greenhouse emissions and global warming.

Development of advanced lithium ion battery and battery management system for electric/hybrid electric vehicle applications

Year Funded:	2009	2010	2011	2012	
	$40,000	$80,000	$80,000	$40,000	
Total Funding:	$240,000				
Project ID:	LP0991012				
Chief Investigators:	Z. P. Guo, H. K. Liu, C. D. Cook, D. Wexler				
Partner Investigator:	H. Zhu, X. J. Zhu				
Industry Partner:	Redarc Electronics, DLG Battery Co. Ltd.				

Project Summary: This project represents a significant scientific and economic development for advanced, high performing, energy storage devices with a focus on safety that will provide enormous benefits for the environment. An added advantage will be the establishment of local and national expertise in the area of electrochemical energy storage systems that will place Australia at the forefront

of lithium ion battery research and development. Flow-on benefits will also be created for Australian organizations involved in the manufacturing of electric vehicles and portable devices.

Magnesium diboride superconductor magnets for applications

Year Funded:	2009	2010	2011
	$100,000	$100,000	$100,000
Total Funding:	$300,000		
Project ID:	LP0989352		
Chief Investigators:	S. X. Dou, X. L. Wang, C. D. Cook, X. Xu		
Partner Investigator:	E. W. Collings,		
Industry Partner:	HyperTech Research Inc., R&D Centre Zenergy Ltd.		

Project Summary: The proposed development of magnesium diboride magnets is one of the core technologies that underlie applications in magnetic resonance imaging, magnetic separators, and other devices. The proposed international research consortium is in a leading position to explore the potential of these superconductor magnets for various applications. A breakthrough in the current proposal will lead to widespread commercial activities in a number of industry sectors: mineral separation, health, electric power, transportation, water purification, drug delivery, and space/aviation. Application of the proposal's outcomes will lead enormous energy savings and environmental benefits.

Novel lithium iron based olivine phosphates as cathode materials for the development of new generation power batteries

Year Funded:	2009	2010	2011
	$125,000	$130,000	$130,000
Total Funding:	$385,000		
Project ID:	LP0989134		
Chief Investigators:	G. X. Wang, D. Wexler, J. Horvat, C. Zhang		
Partner Investigator:	H. Kim		
Industry Partner:	Bezel Science & Technology Australia Pty. Ltd., Daejung Energy Materials Co. Ltd.		

Project Summary: Global warming and climate change are a serious threat to our society today. We must reduce greenhouse gas emissions by using renewable energy for sustainable development. Battery technology is regarded as one of the green technologies that can be widely used to power vehicles and store energy. This project will develop new generation lithium iron power batteries using novel lithium iron based phosphate cathode materials. The success of the research will provide advanced rechargeable batteries for electric bicycles, electric motorcycles and hybrid electric vehicles, contributing to the reduction of CO_2 emissions.

Linkage International Awards

Advanced materials and structures for terahertz science and technology

Years funded:	2007	2008	2009
Amount funded:	$6,500	$10,000	$10,000
Total funding:	$26,500		
Project ID:	LX0776043		
Chief Investigator:	R. A. Lewis, R. Mendis, R. E. M. Vickers		
Partner Investigator:	H. L. Hartnagel, C. Sydlo		

Project Summary: Anthrax, explosives, water, and cancer all have characteristic signatures in the terahertz (THz) part of the electromagnetic spectrum. Security, defence, agriculture, medicine are some of the fields where THz science and technology are booming. THz developments offer enhanced national security, prosperity and quality of life. The lack of strong sources of THz radiation is the main factor hampering wider application of THz methods. In this project two university research teams come together to develop more efficient THz emitters. The Darmstadt team will prepare novel materials and structures and the Wollongong team will evaluate them and provide feedback for the next iteration.

Development of nano-structured thermoelectric materials for power generation from heat

Year Funded:	2008	2009	2010
	$18,000	$20,000	$20,000
Total Funding:	$58,000		
Project ID:	LX0881969		
Chief Investigators:	S. X. Dou, Y. Zhao, G. Peleckis		
Partner Investigators:	X. X. Xi, G. Ramanath, Q. Li		

Project Summary: To make thermoelectric technology attractive for practical power generation purposes, new high efficiency materials have to be developed. Our fabricated nanostructured thermoelectric materials will have improved performance due to the peculiarities in electrical and thermal transport. The novel thermoelectric materials and constructed prototype devices with high thermoelectric performance will be practically used for various power generation purposes. This offers a long-term solution to the global warming threat through decreasing amounts of waste heat presently generated. It will also strengthen Australia's position in world-wide research on thermoelectricity.

Mechanism and enhancement of supercurrent carrying ability in magnesium diboride superconductor

Year Funded:	2008	2009	2010
	$13,000	$18,000	$18,000
Total Funding:	$49,000		
Project ID:	LX0882225		
Chief Investigators:	X. L. Wang		
Partner Investigator:	S. Lee		

Project Summary: The newly discovered MgB_2 superconductor has great potential to replace the existing conventional superconductors for uses in various medical and industrial applications. This project brings together two world leading groups with complementary expertise to develop a fundamental understanding of the factors controlling MgB_2 performance and to find effective ways to significantly improve its supercurrent carrying capabilities for practical applications. The outcome of this project will be of benefit to both countries and will lead to many practical applications such as transformers, rotors, and transmission cables, as well as magnetic resonance imaging without using liquid helium, reducing greenhouse gas emissions and global warming.

Linkage International Fellowships

ARC Linkage International Fellowships

Study on the deposition of superconducting REBCO film via chemical route for coated conductor

Year Funded: 2009
Total Funding: $143,000
Project ID: LX0989591
Chief Investigators: J. H. Kim, S. X. Dou, G. Hong
Fellowship Awarded: G. Hong
Project Summary: Second generation high temperature superconducting (HTS) coated conductor is the essential raw material for the next generation of high efficiency electric power application such as power transmission cables, transformers, motors and generators, and grid protection devices (FCL) as well as medical physics. The high efficiency and compactness of HTS devices promises great savings in energy and reduction in CO_2 emissions, which is vital for decreasing greenhouse effects.

Magnetic walls as nano-manipulators for physics, bio- and medical technologies

Year Funded: 2009
Total Funding: $71,000
Project ID: LX0990073
Chief Investigators: A. V. Pan, T. Johansen
Fellowship Awarded: T. Johansen
Project Summary: The focus of this project is the development of new scientific and technological aspects of nano-manipulators allowing not only the effective control of molecules and other magnetic quantities for a new approach in computation, but also the vital influence of biological processes at the molecular level. The outlook of this idea becomes increasingly promising in science and a broad range of industries (electronics, materials engineering, nanotechnology and biotechnology). This project will establish Australia's advancing area. The outcomes predicted may soon lead to the development of practical devices, where Australian science and industry may play one of the key roles.

Other Non-ARC Grants

High performance nanomaterials for thermionics and thermoelectrics applications

Funding Scheme: DIISR International Science Linkage project

Year Funded:	2008	2009	2010
	$135,000	$85,000	$73,000

Total Funding: $293,000
Chief Investigators: C. Zhang, R. A. Lewis, X. L. Wang, D. Li
Project Summary: Materials of high figure of merit are of paramount importance in developing thermoelectric and thermionic devices. The research on energy materials described in this project is timely as energy is becoming the most critical issue for the prosperity of the world's economy. Thermoelectric/thermionic devices are compact, reliable, silent in operation, and environmentally friendly. They can be integrated with existing fabrication techniques for electronic and optoelectronic devices. This project will advance our fundamental understanding of energy materials derived from nanoscale structures and composites and explore immediate applications in making novel thermoelectric and thermionic devices with high figure of merit for commercialisation.

Development of terahertz emitters based on electronic and hybrid spintronic materials

Funding Scheme:	DIISR International Science Linkage project			
Year Funded:	2007	2008	2009	2010
	$50,000	$50,000	$50,000	$50,000
Total Funding:	$200,000			
Chief Investigators:	C. Zhang, R. A. Lewis, J. Horvat, R. Vickers, W. Xu, J. Xi			

Project Summary: High power, broad bandwidth terahertz (THz) sources are of great importance to many areas of science and technology and have wide applications in medical diagnosis, communication, and national security. The key challenge in this field is to find high efficiency radiation sources. The THz frequency falls in the gap between electronics and photonics. This vital THz gap has opened up a new field of study, termed THz science and technology. To date, the electronic devices struggle to generate waves much above 500GHz and infrared source becomes very dim as wavelength approaches the THz region. This project aims to solve some of the challenges in developing better terahertz devices.

URC Small Grants & ARC Near-Miss Grants 2009

The evolution of solar energy in photo electrochemical cells using nano-materials

Total Funding: $12,000
Chief Investigators: J. H. Kim, Y. Zhao

Exploration of novel highly effective electrocatalysts for proton exchange membrane fuel cells

Total Funding: $14,000
Chief Investigators: Z. P. Guo

Synthesis of $ZnCr_2Se_4$ nanoparticles

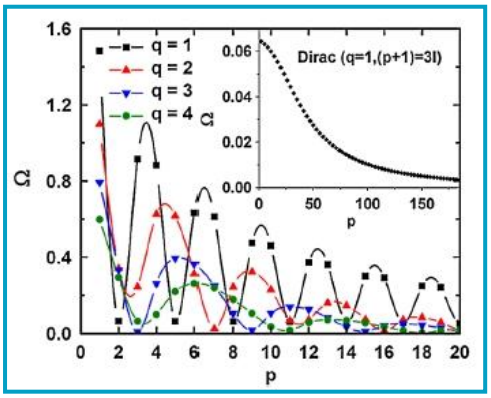
Total Funding: $14,000
Chief Investigators: J. Horvat

Titanium dioxide 101: Characterisation and utilisation of well defined single crystal TiO_2/dye surfaces for solar energy conversion

Total Funding: $14,000
Chief Investigators: G. Peleckis, A. Mozer, D. P. Chen

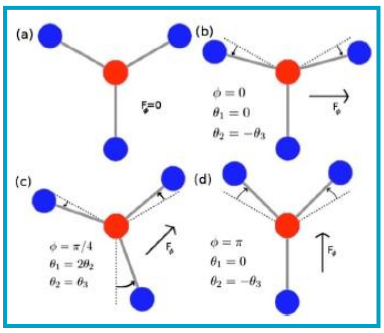
Selected Abstracts

Enhanced optical conductivity of bilayer graphene nanoribbons in the Terahertz regime



We reveal that there exists a class of graphene structures (a subclass of bilayer graphene nanoribbons) which has an exceptionally strong optical response in the terahertz (THz) and far infrared (FIR) regime. The peak conductance of THz/FIR active bilayer ribbons is around 2 orders of magnitude higher than the universal conductance observed in graphene sheets. The criterion for the THz/FIR active subclass is a bilayer graphene nanoribbon with a one-dimensional massless Dirac fermion energy dispersion near the Γ point. Our results overcome a significant obstacle that hinders the potential application of graphene in electronics and photonics. (A. R. Wright et al., *Physical Review Letters* **103**, 207401 (2009))

Stretching induced Hall current and conductance anisotropy in graphene

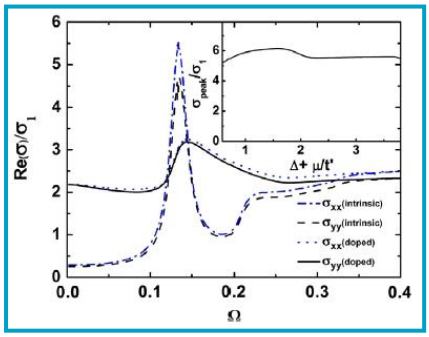


We evaluate the effect of stretching on the optical conductance of a single layer graphene sheet. It is found that the low energy (Dirac regime) isotropy that leads to the `universal conductance' is lost. More significantly, due to the loss of C_3 symmetry, a non-zero Hall conductance emerges for stretching along chiral directions, reaching a maximum at a stretching angle of 45 degrees, and being as high as $\sigma_0 = e^2/4\hbar$ at van Hove singular point for bond angle changes of about 2 degrees. (A. R. Wright et al., *Applied Physics Letters* **95**, 163104 (2009))

Strong nonlinear optical response in graphene in terahertz regime

We demonstrate that within the model of massless Dirac fermions, graphene has a strong nonlinear optical response in the terahertz regime. It is found that the nonlinear contribution significantly alters both the single frequency and frequency tripled optical response at experimentally relevant field strengths. The optical activity of single layer graphene is significantly enhanced by nonlinear effects, and the frequency tripled response opens the gateway to photonic and optoelectronic device applications. (A. R. Wright et al., *Applied Physics Letters* **95**, 072101 (2009))

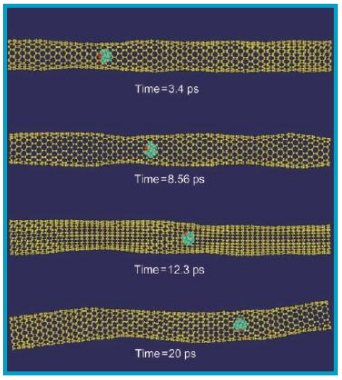
Effect of next-nearest neighbour coupling on the optical spectra in bilayer graphene



We investigate the dependence of the optical conductivity of bilayer graphene (BLG) on the intra and interlayer interactions using the most complete model to date. We show that the next nearest neighbour intra-layer coupling introduces new features in the low energy spectrum significantly changing the universal conductance. Further, its interplay with interlayer couplings leads to an anisotropy in the conductance in the ultraviolet range. We propose that experimental measurement of the optical conductivity of intrinsic and doped BLG will provide a good benchmark for the relative importance of intra and interlayer couplings at different doping

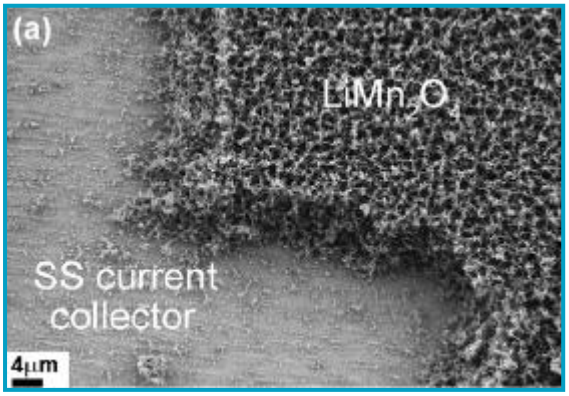
levels. (A. R. Wright et al., *Nanotechnology* **20**, 405203 (2009))

Nanopumping molecules via a carbon nanotube



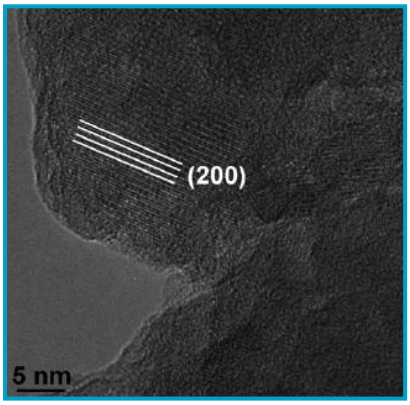
We demonstrate the feasibility of using a carbon nanotube to nanopump molecules. Molecular dynamics simulations show that the transport and ejection of a C_{20} molecule via a single-walled carbon nanotube (SWNT) can be achieved by a sustained mechanical actuation driven by two oscillating tips. The optimal condition for nanopumping is found when the tip oscillation frequency and magnitude correlate to form quasi steady-state mechanical wave propagation in the SWNT, so that the energy transfer process is optimal leading to maximal molecular translational motion and minimal rotational motion. Our finding provides a potentially useful mechanism for using an SWNT as a vehicle to deliver large drug molecules. (M. Chen et al., *Nano Research* **2**, 938 (2009))

Thin nanostructured $LiMn_2O_4$ films by flame spray deposition and *in situ* annealing method



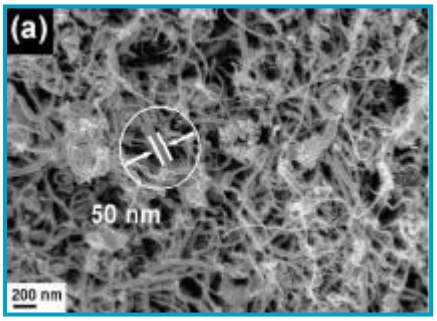
A new approach has been developed to rapidly synthesize nanostructured $LiMn_2O_4$ thin films by flame spray deposition (FSD) and *in situ* annealing. A precursor solution of lithium acetylacetonate and manganese acetylacetonate in an organic solution was supplied through a flame spray pyrolysis (FSP) reactor. The liquid solution spray was ignited and stabilized by a premixed methane/oxygen flame ring surrounding the FSP nozzle. Thus, $LiMn_2O_4$ nanoparticles were formed by combustion and deposited onto a current collector followed by *in situ* annealing. Two different types of current collectors, i.e. stainless steel and aluminium coated with carbon-based primer were tested. The prepared thin films were characterized by X-ray diffraction and field-emission scanning electron microscopy. The electrochemical properties of the thin films were evaluated by cyclic voltammetry and galvanostatic cycling. The $LiMn_2O_4$ films exhibited good cyclability. Films that underwent sintering and crystal growth during *in situ* annealing developed more robust film structures on the current collector surface and exhibited better electrochemical performance than poorly adhered films. (S. Y. Chew et al., *Journal of Power Sources* **189**, 449 (2009))

Flame spray-pyrolyzed vanadium oxide nanoparticles for lithium battery cathodes



Vanadium pentoxide (V_2O_5) nanoparticles (30–60 nm) were made by a one-step and scalable flame spray pyrolysis (FSP) process. Optimization of the FSP processing conditions (precursor concentration and injection rate) enhanced the electrochemical performance of these nanoparticles. Increasing the cut-off potential for discharging from 1.5 to 2.5 V vs. Li/Li^+ improved the cycle life of these V_2O_5 nanoparticles. Particles with the lowest specific surface area (32 m^2/g) and highest phase purity (up to 98 wt%) showed excellent cyclability between 2.5 and 4.0 V vs. Li/Li+, retaining a specific charge of 110 mAh/g beyond 100 cycles at a specific current of 100 mA/g, and also superior specific charge of 100 mAh/g at specific current up to 20C rate (or 2000 mA/g). (S. H. Ng et al., *Physical Chemistry Chemical Physics* **11**, 3748 (2009))

Flexible free-standing carbon nanotube films for model lithium-ion batteries,

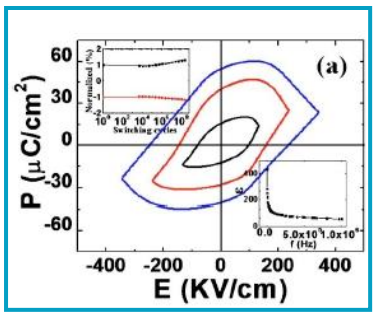


A comparative study of conductive, free-standing, binder-free flexible films made from three different types of commercial carbon nanotubes (CNTs), i.e., single-wall, double-wall, and multi-wall was carried out. The conductive CNT films were prepared by adding the CNTs to the starting dispersion of carbon black and Triton X-100, followed by a vacuum filtration technique. These films have been characterized as model free-standing, binder-free electrodes for flexible lithium-ion batteries. Our experiments revealed that films based on multi-wall CNTs (MWCNTs) are much better than single-wall and double-wall CNTs films in terms of their electrochemical performance. The flexible MWCNT electrodes show stable cycling behaviour and allow up to a 10 C-rate. (S. Y. Chew et al., *Carbon* **47**, 2976 (2009))

Peeling adhesive tape emits electromagnetic radiation at terahertz frequencies

An unusual concept for a simple and inexpensive terahertz source is presented: unpeeling adhesive tape. The observed spectrum of this terahertz radiation exhibits a peak at 2 THz and a broader peak at 18 THz. The radiation is not polarized. The mechanism of terahertz radiation is tribocharging of the adhesive tape and subsequent discharge, possibly bremsstrahlung with absorption or energy density focusing during the dielectric breakdown of a gas. The accompanying optical emission is also a consequence of tribocharging. (J. Horvat and R. A. Lewis, *Optics Letters* **34**, 2195 (2009))

Room temperature multiferroic properties of Nd:$BiFeO_3$/Bi_2FeMnO_6 bilayered films



$Nd_{0.1}Bi_{0.9}FeO_3$ /Bi_2FeMnO_6 bilayered films were deposited on Pt/Ti/SiO_2 / Si substrate by pulsed laser deposition method. $BiFeO_3$ is antiferromagnet while $BiMnO_3$ is ferromagnet, the ordering of –Mn–O–Fe–O–Mn– is expected, which will induce the ferromagnetic interaction in the film. The film shows typical ferromagnetic properties with the transition temperature of Tc of 440 K. The room temperature (RT) ferroelectric polarization was also observed, suggesting that the film is a promising RT multiferroism. (H. Y. Zhao et al., *Applied Physics Letters* **95**, 232904 (2009))

Comparison of photo excited *p*-InAs THz radiation source with conventional thermal radiation sources

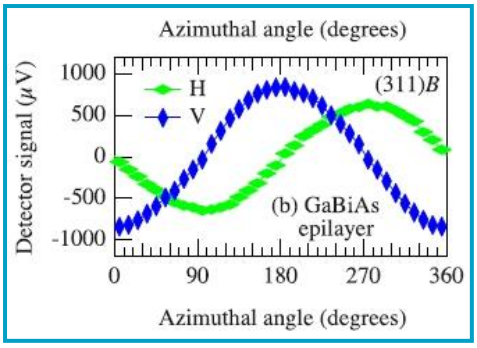
P-type InAs excited by ultrashort optical pulses has been shown to be a strong emitter of terahertz radiation. In a direct comparison between a *p*-InAs emitter and conventional thermal radiation sources, we demonstrate that under typical excitation conditions *p*-InAs produces more radiation below 1.2 THz than a globar. By treating the globar as a blackbody emitter we calibrate a silicon bolometer which is used to determine the power of the *p*-InAs emitter. The emitted terahertz power was found to be 98 10 nW in this experiment. (M. L. Smith et al., *Journal of Applied Physics* **105**, 063109 (2009))

Very high critical field and superior J(c)-field performance in $NdFeAsO_{0.82}F_{0.18}$ with T-c of 51 K

A new family of oxypnictide superconductors, $LaFeAsO_{0.89}F_{0.11}$, brings new impetus to the field of

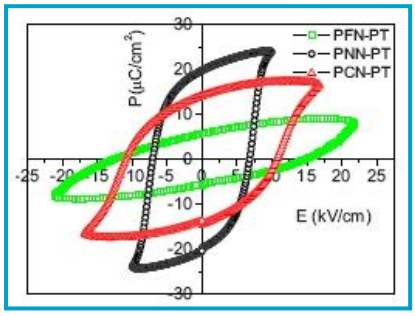
high-temperature superconductivity. In this work, we show that the upper critical field values H,2 (48 K) = 13 T and H-c2(0) can exceed 80-230 T in a high-pressure-fabricated $NdO_{0.82}F_{0.18}FeAs$ bulk sample with T_c of 51 K. We also demonstrate the superior performance of supercurrent density in fields for this new superconductor. (X. L. Wang et al., *Advanced Materials* **21**, 236 (2009))

The role of optical rectification in the generation of terahertz radiation from GaBiAs



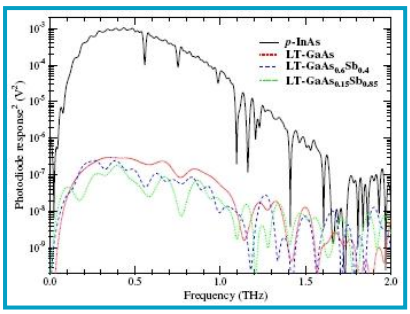
We report on a detailed study of the emission of terahertz-frequency electromagnetic radiation from layers of GaBi*y*As1−*y* 0 *y* 0.04 grown by molecular beam epitaxy on 311 *B* and 001 GaAs substrates. We measure two orthogonally polarized components of the terahertz radiation emitted under excitation by ultrashort near-infrared laser pulses in both transmission and reflection geometries as a function of the crystal rotation about its surface normal as well as the effect of in-plane magnetic field and pump fluence on the terahertz emission. We conclude that the principal mechanism for terahertz generation is via optical rectification rather than transient currents. (K. Radhanpura et al., *Applied Physics Letters* **94**, 251115 (2009))

Magnetic glassy behaviour in ferroelectric relaxor type solid solutions: Magnetoelectric relaxor



Perovskite solid solution ceramics with compositions of $0.9Pb(Fe_{0.5}Nb_{0.5})O_3–0.1PbTiO_3$, $0.6Pb(Ni_{1/3}Nb_{2/3})O_3–0.4PbTiO_3$, and $0.6Pb(Co_{1/3}Nb_{2/3})O_3–0.4PbTiO_3$ were synthesized by the traditional solid state reaction method. Ferroelectric measurements revealed that these samples have well saturated polarization-electrical field loops. Dielectric measurements showed that abnormal dielectric peaks at their Curie temperature were frequency dependent. Both characteristics indicate that these samples are relaxor type ferroelectric materials. Field cooled and zero field cooled magnetization measurements revealed that the $0.6Pb(Ni_{1/3}Nb_{2/3})O_3–0.4PbTiO_3$ and $0.6Pb(Co_{1/3}Nb_{2/3})O_3–0.4PbTiO_3$ samples are paramagnetic down to 5 K, while the $0.9Pb(Fe_{0.5}Nb_{0.5})O_3–0.1PbTiO_3$ sample shows an antiferromagnetic-like ordering starting from around 40 K. Furthermore, a weak ferromagnetism is observed in the $0.9Pb(Fe_{0.5}Nb_{0.5})O_3$ $–0.1PbTiO_3$ sample, as evidenced by the magnetic hysteresis loop measured at 10 K. The ac susceptibility measurement of this sample showed that the peak position around 40 K is strongly dependent on frequency, indicating a glassy or relaxor type behaviour below that temperature. Therefore, relaxor type ferroelectric and magnetic $0.9Pb(Fe_{0.5}Nb_{0.5})O_3–0.1PbTiO_3$ is a magnetoelectric relaxor. (Z. X. Cheng et al., *Journal of Applied Physics* **105**, 07D902 (2009))

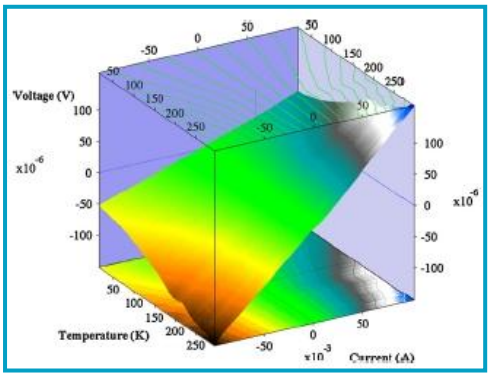
New modes of THz generation by low-temperature-grown GaAsSb



The low-temperature growth of $GaAs_{1-y}Sb_y$ with y = 0.4 and 0.85 has been reported recently along with characterization by X-ray diffraction, Hall, and current–voltage measurements. Here we extend the characterization by employing reflectance spectroscopy in the range 5–18 THz to confirm the compositions of the grown layers. In the course of this work we established for the first time that $GaAs_{1-y}Sb_y$ may serve as an emitter of THz radiation under optical excitation by ultrashort pulses of near-infrared radiation in two distinct experimental arrangements: THz is generated when an electrical bias

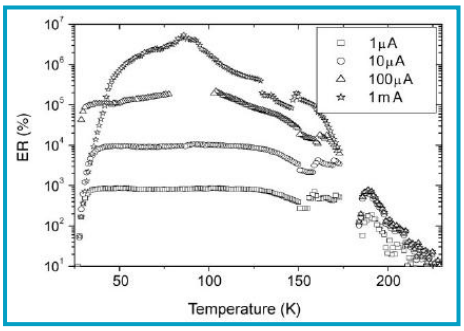
is applied through a simple electrode structure, attributed to a photoconductive effect; and THz is generated by the pristine layers themselves, attributed to a surface-field effect. In each case the THz emission is compared directly with that from low-temperature-grown GaAs. The results presented here are for as-grown material. Suitable annealing may improve the THz emission even further. (S. Hargreaves et al., *Solid State Electronics* **53**, 160 (2009))

Small electroresistance (SER) in bulk $La_{2/3}Sr_{1/3}MnO_3$ below TC



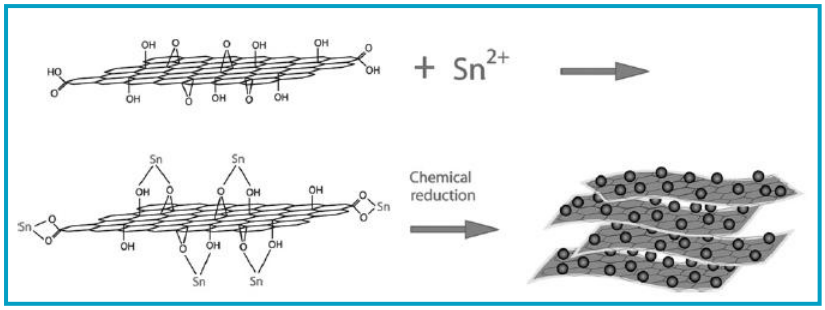
The voltage drop across a bulk polycrystalline sample of $La_{2/3}Sr_{1/3}MnO_3$ was measured at applied currents in the range ±100mA at temperatures from 15 to 295 K. Under these conditions, the sample is essentially metallic. The *V–I* curves are close to linear. The resistance generally decreases with temperature, although there is a small peak in resistance at ~ 200K. The electroresistance (ER) is small, rarely exceeding 10% over this range of temperatures and currents. This small electroresistance (SER) observed in the bulk material is in contrast to the "giant" or "colossal" electroresistance (GER, CER) reported previously in thin films of $La_{2/3}Sr_{1/3}MnO_3$ and indicates that the anisotropy in thin films plays a key role in determining the magnitude of the electroresistance. (R. A. Lewis, *Journal of Alloys and Compounds* **471**, 368 (2009))

Colossal electroresistance and giant magnetoresistance in doped $PbPdO_2$ thin films



Observations on colossal electroresistance (ER) and giant magnetoresistance in doped $PbPdO_2$, one of the candidates of a new class of materials, spin gapless semiconductors, are reported. The resistivity is strongly suppressed by electrical current below a metal-insulator transition with the ER values of up to 10^7, which is much greater than that achieved in colossal magnetoresistance materials. (X. L. Wang et al., *Advanced Materials* **21**, 2196 (2009))

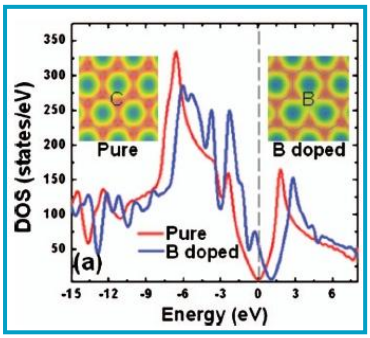
Sn/graphene nanocomposite with 3D architecture for enhanced reversible lithium storage in lithium ion batteries



A general strategy has been demonstrated to achieve optimum electrochemical performance by constructing 3D nanocomposite architecture with the combination of nanosize Sn particles and graphene nanosheets. In the first step, the lithium storage properties of graphene have been investigated by first principles calculations. The results show that lithium can be stably stored on both sides of graphene sheets (LiC_3), inducing in a theoretical capacity of 744 mAh/g. In the second step, a synthetic approach has been designed to prepare Sn/graphene nanocomposite with 3D architecture, in which Sn nanoparticles act as a spacer to effectively separate graphene nanosheets. FESEM and TEM analysis revealed the homogeneous distribution of Sn nanoparticles (2-5 nm) in graphene nanosheet matrix. Cyclic voltammetry measurement has proved the highly reversible nature of the reaction between Li+

and Sn/graphene nanocomposite. The 3D nanoarchitecture gives the Sn/graphene nanocomposite electrode an enhanced electrochemical performance. This strategy can be extended to prepare other anode and cathode materials for advanced energy storage and conversion devices such as lithium ion batteries, supercapacitors, and fuel cells. (G. X. Wang et al., *Journal of Materials Chemistry* **19**, 8378 (2009))

First-principles study on the enhancement of lithium storage capacity in boron doped graphene

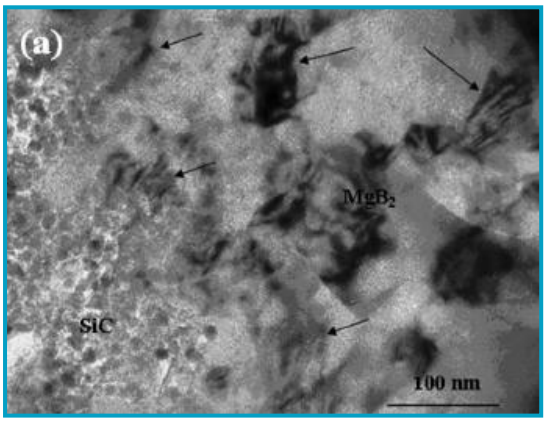


The adsorption of Li ions on boron doped graphene was investigated using a first-principles method. Our results show that, as boron doping turns graphene into an electron-deficient system, more Li ions can be captured around boron doped centres than in pristine graphene. One boron atom doped into graphene (6C ring unit) can adsorb six Li ions, which indicates that boron doped graphene is an efficient Li-ion storage material for lithium batteries. Further investigations show that, under limited conditions, boron doped graphene (BC_5) can form Li_6BC_5 compound after Li-ion adsorption, corresponding to a lithium storage capacity of 2271 mAh/g which is six times that of graphite. (X. L. Wang et al., *Applied Physics Letters* **95**, 183103 (2009))

Foam-like, microstructural SnO_2–carbon composite thin films synthesized *via* a polyol-assisted thermal decomposition method

Foam-like, microstructural SnO_2–carbon composite thin films were synthesized by refluxing $SnCl_2{\cdot}2H_2O$ in ethylene glycol (EG) at 195 °C for 4 h under vigorous stirring in air followed by thermal decomposition of the as-synthesized precursor solution, whereby the products were deposited onto stainless steel (SS) substrates. Subsequently, the decomposed product, which now consists only of the microstructural SnO_2–carbon composite thin film, without the addition of any binder and carbon black conductive agent, was directly applied as an anode material for use in a Li-ion rechargeable battery. Physical and electrochemical characterizations of the as-synthesized thin films were carried out. The foam-like, microstructural SnO_2–carbon composite thin films that undergo thermal decomposition in air at 300 °C demonstrated the best cyclability, delivering a specific discharge capacity of approximately 496 mAh/g beyond 100 cycles. We believe that the presence of a uniform, SnO_2–carbon network throughout the foam-like thin film, acts not only as an improved conducting network but also buffered the volume expansion upon Li–Sn alloying, resulting in a much improved cycling of the composite thin film electrode. (S.-H. Ng et al., *Dalton Transactions* **4**, 723 (2009))

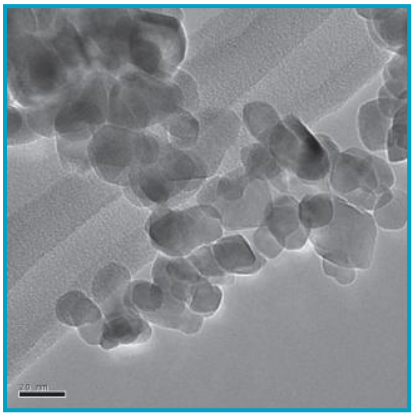
Thermal-strain-induced enhancement of electromagnetic properties of SiC–MgB_2 composites



The effect of thermal strain caused by the different thermal expansion coefficients of the MgB_2 and SiC phases on the electromagnetic properties was studied for SiC–MgB_2 composite, which was made by premixing SiC and B, followed by Mg diffusion and reaction. Thermal strain in the MgB_2 phase was demonstrated with x-ray diffraction, Raman spectroscopy, and transmission electron microscopy. In contrast to the common practice of improving the critical current density *Jc* and the upper critical field *Hc*2 of MgB_2 through chemical substitution, by taking advantage of residual thermal strains, we are able to design a composite showing only a small decrease in the critical temperature

and a little increase in resistivity but a significant improvement over the *Jc* and *Hc*2 of pure MgB_2. (R. Zeng et al., *Applied Physics Letters* **94**, 042510 (2009))

Microwave synthesis of homogeneous YAG nanopowder leading to a transparent ceramic



A homogeneous and extremely fine yttrium aluminum garnet (YAG) precursor powder was synthesized from solutions with a low [urea]/[metal ions] ratio under microwave irradiation, and pure phase YAG was directly crystallized from it at 1173 K. In the presence of sulphate ions, a fibrillar precursor that takes on a dendritic skeleton was generated, and easily dispersible YAG nanopowder with a particle size of 20–30 nm was obtained at 1373 K. A transparent YAG ceramic with fine grains was sintered from this YAG nanopowder at 1973 K for 10 min in a graphite furnace. At the wavelength of 1060 nm, the in-line light transmittance of the YAG ceramic is up to 67%. The mechanism behind the influence of the microwave irradiation and sulphate ions on the characteristics of YAG is thoroughly discussed. (J. Q. Wang et al., *Journal of the American Ceramic Society* **92**, 1217 (2009))

Conferences

33rd Annual Condensed Matter and Materials Meeting (3rd to 6th February 2009, Wagga Wagga, Australia)

Session Chair: R. A. Lewis

"The emission of visible radiation by peeling adhesive tape", E. Constable, Y. Hu, J. Horvat and R. A. Lewis

"Ultrafast interactions in condensed matter as source of terahertz-frequency electromagnetic radiation", S. Hargreaves and R. A. Lewis

"Studies of the electroresistive properties of electronic oxides", J. C. Knott and R. A. Lewis

"The generation of terahertz frequency radiation by optical rectification", K. Radhanpura, S. Hargreaves and R. A. Lewis

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International Workshop on Electronic Materials and Their Applications (19th to 20th March 2009, Wollongong, Australia)

Organizing Committee: S. X. Dou, X. L. Wang, R. A. Lewis

"Terahertz transmittance of bilayer graphene nanoribbons", C. Zhang (Invited)

International Conference on Processing & Manufacturing of Advanced Materials (25th to 29th August 2009, Berlin, Germany)

Session Chair: Z. P. Guo

"Silicon and tin-based anode materials for lithium ion batteries", Z. P. Guo (Invited)

9th International Conference on Research in High Magnetic Fields (22nd to 25th July 2009, Dresden, Germany)

International Advisory Committee: R. A. Lewis

Conference on Lasers and Electro Optics/Pacific Rim (CLEOPR) (30th August to 3rd September 2009, Shanghai, China)

Session Chair: C. Zhang, R. A. Lewis

"Terahertz transmittance of bilayer graphene nanoribbons", C. Zhang (Invited)

9th International Conference on Materials and Mechanisms of Superconductivity (M^2S-IX) (7th to 12th September 2009, Tokyo, Japan)

"Study of superconductivity, microstructure, phase composition of MgB_2 after co-doping with Zn and C", S. H. Zhou

"Preparation of YBCO films for microwave application using a hybrid route", D. Q. Shi

"Metastable behaviour and effects of initial state of vortex matter in the Type-II superconductor", D. Q. Shi

"The mechanism of Tc performance for Zn doped MgB_2 sintered in magnetic field", W. X. Li

"The effects of lattice distortion on the superconductivity for nano SiC doped MgB_2", W. X. Li

"Synthesis and characteristics of MgB_2 bulks with different densities", R. Zeng

"Lattice strain and superconducting properties of MgB_2", R. Zeng

"Effects of processing atmosphere on critical current density of MgB_2", Y. Zhang

"Model explaining magnetic phases and behaviour in Ruthenium-based superconducting ferromagnets", A. V. Pan

"Flux pinning mechanism, critical current density, microstructures, thermoelectricity, and valences of Fe in $(Ba,K)Fe_2As_2$ and REFeAsO", X. L. Wang

"Vortex pinning model and regimes in $YBa_2Cu_3O_7$ superconducting films", A. V. Pan

"Effects of toluene (C_7H_8) addition on microstructure and superconducting properties of bulk $C_6H_{10}O_6Fe$+SiC doped MgB_2", S. Quddus

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34th International Conference on Infrared and Milimeter Waves and Terahertz Electronics (21st to 25th September 2009, Pusan, Korea)

Member of International Advisory committee, C. Zhang

"Nanomaterial Spectroscopy", Session Chair, C. Zhang

"Terahertz transmittance of bilayer graphene", C. Zhang (Invited)

International Symposium on Renewable Energy Storage and Conversion Technologies (18th to 20th November 2009, University of Wollongong, Australia)

Members of organizing committee: G. X. Wang, H. K. Liu, Z. P. Guo, J. Wang, S. X. Dou

"Nanomaterials and nanotechnologies for Li-ion rechargeable batteries", H. K. Liu

"Sulphur and sulphide cathode materials for rechargeable lithium batteries", J. Z. Wang

"Porous nanostructures as anode materials for lithium ion batteries", Z.P. Guo

"Synthesis and chemical modification of graphene for energy storage and conversion", G. X. Wang

"Application of advanced nano-ceramic composites in supercapacitors", K. Konstantinov

"Introduction to new Processing & Devices building and facilities: an UOW initiative towards commercialization of scientific research outcomes", S. X. Dou

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16th AINSE Conference on Nuclear and Complementary Techniques of Analysis (25th to 27th November 2009, Sydney, Australia)

"Buckling induced patterns in thin confined elastic films by ion implantation", B. Winton

Honorary Appointment in Overseas Institutes

S. X. Dou

Asia Materials, Branch of Nature Materials, Advisory Committee

Beijing University of Science and Technology, Beijing, China

Hubei University, China

Shanghai University, China

Institute of Electrical Engineering, Chinese Academy of Sciences, China

Open Materials Science Journal, Editor Board Member

Rare Earth Metals, Associate Editor

Shanghai Institute of Microsystems and Information Technology, Chinese Academy of Sciences, Shanghai, China

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H. K. Liu

Advanced Science Letters, Associate Editor

Hubei University, China

Shanghai University, China

Journal of Nanoscience and Nanotechnology, Editorial Board Member

Journal of New Materials for Electrochemical Systems, Advisory Board Member

Shanghai Institute of Microsystems and Information Technology, Chinese Academy of Sciences, Shanghai, China

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C. Zhang

Institute of Solid State Physics, Chinese Academy of Sciences

Shanghai Institute of Microsystems and Information Technology, Chinese Academy of Sciences, Shanghai, China

Tianjin University, Tianjin, China

Xi'an Institute of Optics and Precise Mechanics, Chinese Academy of Sciences, Xi'an, China

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Z. P. Guo

East China University of Science and Technology

Xinjiang University

Invited Presentations / Seminars at Other Institutions

S. X. Dou

"Research progress on MgB_2 superconductors at ISEM"
International Workshop on Electronic Materials, University of Wollongong, Wollongong, Australia, March 2009

"Postgraduate training and research program at ISEM"
East China University of Science & Technology, China, July 2009

"Control of nano-structure to enhance materials performance properties"
Institute of Electrical Engineering, Chinese Academy of Sciences, China, July 2009

"Strain engineering"
ISEM-CSIRO Workshop, University of Wollongong, Wollongong, Australia, August 2009

"Critical current density and flux pinning of MgB_2 wire"
Applied Superconductivity and Electromagnetic Devices, Chengdu, China, September 2009

"Chemical doping and strain engineering for improvement of critical current density and flux pinning of MgB_2 wire"
Southwestern Jiao Tong University, Chengdu, China, September 2009

"Introduction to ISEM research program"
Jiang Su University, Zhenjiang, China, October 2009

"Chemical doping and strain engineering for materials design and formulation"
Yonsei University, Seoul, South Korea, October 2009

"Research progress on development of nanomaterials for energy applications at ISEM"
Korean Advanced Institute of Science & Technology, South Korea, October 2009

"Strategic postgraduate training leads to sustainable research excellence at ISEM"
International Conference for Western Return Chinese Scholars, Sydney, Australia, November 2009

"Chemical doping and strain engineering for materials design and formulation"
International Symposium on Energy Storage and Conversion, Wollongong, Australia, November 2009

"Research excellence through postgraduate student training"
Federation of Chinese Australian Scholars, Gold Coast, Australia, November 2009

C. Zhang

"Optical properties of graphene"
Peking University, China, September 2009

"Dynamic conductance of graphene and graphene nanoribbons"
Jilin University, China, April 2009

"Nonlinear optical spectra of graphene"
Jiangsu University, China, September 2009

"Terahertz photonics in graphene"
Institute of Solid State Physics, Chinese Academy of Sciences, China, September 2009

R. A. Lewis

"Terahertz science and technology"
Australian Institute of Physics, Sydney, Australia, March 2009

"Optical rectification for terahertz generation"
Technical University of Darmstadt, Germany, July 2009

"THz"
Australian Experimental High Energy Physics Meeting, Wollongong, Australia, December 2009

Z. P. Guo

"Three-dimensional nanostructures for lithium ion batteries"
East China University of Science and Technology, April 2009

"One-dimensional porous nanomaterials for energy storage"
Shanghai Jiaotong University, December 2009

J. Horvat
"Peak effect in MgB_2/Fe superconducting wires: interaction between superconductor and ferromagnet"
Institute of Physics of the University of Zagreb, Zagreb, Croatia, April 2009

H. K. Liu

"Energy materials research program"
25th Anniversary Forum, Women in Science Enquiry Network, University of Wollongong, Wollongong, Australia, November 2009

Seminars by Visiting Scientists

Date	Name	Institute	Title
03/02/2009	Prof. Harald W. Weber	Atomic Institute, Vienna University, Austria	Superconducting fusion magnets
06/02/2009	Prof. Jung Ho Ahn	Department of Materials Engineering, Andong National University, Korea	Grain connectivity of MgB_2 superconducting material
19/03/2009	Mr. Michael Tomsic	Hyper Tech Research Inc., USA	Latest properties of MgB_2 superconductor wires plus discussion of MgB_2 rotor and stator coils for rotating power equipment
19/03/2009	Dr. Gianni Grasso	Columbus Superconductors, Italy	Development of ex-situ MgB_2 wires and their applications
19/03/2009	Prof. Rene Flukiger	University of Geneva, Switzerland	Enhancement of Jc and Birr of binary and alloyed in situ MgB_2 wires and tapes by a new treatment: cold high pressure densification
19/03/2009	Prof. Edward Collings	Ohio State University, USA	Flux pinning and connectivity in SiC doped MgB_2
19/03/2009	Dr. Hiroaki Kumakura	National Institute for Materials Science, Japan	Densification of MgB_2 layers in MgB_2 tapes and wires
19/03/2009	Prof. Teruo Matsushita	Kyushu Institute of Technology, Japan	Flux pinning properties of radiation induced columnar defects in DyBCO coated conductor
19/03/2009	Prof. Chennupati Jagadish	Australian National University, Australia	Nanowires for optoelectronic device applications
19/03/2009	Prof. Robert Stamps	The University of Western Australia, Australia	Turbulent transitions and frustrated states: some issues in reversal
19/03/2009	Dr. Carl Xianguyan Cui	The University of Sydney, Australia	Semiconductor spintronics via computational simulations
19/03/2009	Dr. Ben Powell	The University of Queensland, Australia	Strong correlations in organic charge transfer salts: superconductors, Mott insulators bad metals and spin liquids
19/03/2009	Prof. Ekkes Bruck	Delft University of Technology, The Netherlands	Magnetocaloric materials not only for cooling applications
19/03/2009	Dr. Karl Heinz Muller	Australian Commonwealth Scientific and Research Organization, Australia	High thermoelectric figure of merit in a molecule semiconductor hybrid material
19/03/2009	Prof. Stewart Campbell	The University of New South Wales, Australia	The magnetism of rare earth intermetallic compounds – a platform for designed magnetocaloric materials
19/03/2009	Dr. Sean Li	The University of New South Wales, Australia	Atomic stoichiometric ratio optimization of $Na_xCo_2O_{4-\delta}$ for power generation
20/03/2009	Prof. Ganapathiraman Ramanath	Centre for Future Energy Systems, Rensselaer Polytechnic Institute, USA	Sculpted nanomaterials and engineered interfaces for emerging energy applications

Date	Name	Institute	Title
20/03/2009	Prof. Tom Johansen	Department of Physics, University of Oslo, Norway	Magnetic walls creating colloidal micromachines
20/03/2009	Prof. Liangchi Zhang	The University of Sydney, Australia	Cross scale mechanics of carbon nanotubes
20/03/2009	Dr. Robert Buckley	Industrial Research Ltd., New Zealand	Applications of HTS wire and cable
20/03/2009	Prof. Gye Won Hong	Korea Polytechnic University, Korea	Preparation of silver protecting layer for coated conductor using solution based deposition
20/03/2009	Dr. Kookchae Chung	Korea Institute of Materials Science, Korea	Research on flux pinning technology of superconducting materials in KIMS
20/03/2009	Dr. Jeff Moscrop	Zenergy Power Ltd., Australia	Design, development and testing of a saturable core HTS fault current limiter by Zenergy Power
04/06/2009	Prof. Tom Johansen	Department of Physics, University of Oslo, Norway	Magnetic domains and particle manipulation
22/07/2009	Dr. A. Glushenkov	Australia National University, Australia	Synthesis of VN nanoparticles
26/08/2009	Prof. Cathy Foley	Australian Commonwealth Scientific and Research Organization, Australia	CSIRO advanced materials research program
26/08/2009	Dr. Karl Heinz Muller	Australian Commonwealth Scientific and Research Organization, Australia	Superconductivity in iron-pnictides
26/08/2009	Dr. Emma Mitchell	Australian Commonwealth Scientific and Research Organization, Australia	YBCO step edge Josephson junctions, mill Kelvin measurements and microwaves
26/08/2009	Dr. Simon Lam	Australian Commonwealth Scientific and Research Organization, Australia	Spin measurement of magnetic molecules using a Nano SQUID
15/09/2009	Prof. Daniel Grischkowasky	School of Electrical and Computer Engineering, Oklahoma State University, USA	THz photonics: unique characteristics, accomplishments and future potential
31/10/2009	Prof. Feng Liu	Department of Materials Science and Engineering, University of Utah, USA	Quantum manifestations of graphene edge stress and edge instability
30/11/2009	Prof. Oleg P. Sushkov	School of Physics, University of New South Wales, Australia	Spin spirals in underdoped $La_{2-x}Sr_xCuO_4$ and $YBa_2Cu_3O_{6+y}$: differences and similarities
01/12/2009	Prof. John Clarke	Department of Physics, University of California, USA	The Ubiquitous SQUID: from cosmology to medicine
11/12/2009	Dr. Thomas Saerbeck	Australian Nuclear Science & Technology Organization, Australia	Polarized neutron reflectometry – applications on vertical and lateral patterned magnetic media

Equipment and Facilities

In 2008 ISEM expanded its laboratory space from approx. 420 m^2 and 9 labs in main campus to approx. 900m^2 and 21 labs in the new AIIM facility at the Innovation Campus. This expansion allowed us to dedicate space to research specific areas and diversify our research teams. The laboratories are ranging from general sample processing for various kinds of materials to sophisticated single crystal growth lab, low temperature laboratory, energy and hydrogen testing laboratories, etc.

The majority of these facilities were founded through 7 ARC RIEF programs and the Metal Manufactures Ltd Consortium program over the past ten years, as well as additional funds were allocated from the relocation budget considering great increase in the laboratory space. Through relocation funds ISEM purchased Mettler Toledo TGA/DTA for materials characterization, powerful solid state laser (Quanta Ray) for deposition of thin films and optical table, four mirror floating zone single crystal growth facility (CSC Corporation) for growth of large high quality single crystals, new GBC MMA XRD machine with most up-to-date PDF2 database, and other minor equipment.

The following institutions and Chief Investigators have been involved with the ARC RIEF/LIEF proposals in the past:

Australian Nuclear Science & Technology Organisation	Dr. M. Ionescu, Dr. S. Kennedy, Dr. F. Klose
James Cook University	Prof. J. Mazierska, A/Prof. M. Jacob
Macquarie University	A/Prof. E. Goldys
Monash University	Dr. Y. B. Cheng, Dr. R. Krishanmurthy
University of Melbourne	A/Prof. D. N. Jamieson
University of New South Wales	Prof. M. Skyllas-Kazacos, Dr. S. Li, Dr. R. Ramer, Prof. S. Campbell
University of Queensland	Prof. M. G. Lu, Dr. L. Wang, Prof. D. R. Mackinnon
University of Sydney	Prof. S. Ringer, Prof. C. Stampfl, Prof. L. Z. Zhang, Dr. R. K. Zheng, Dr. X. Z. Liao
University of Technology, Sydney	Prof. J. G. Zhu, Dr. J. Lin, Prof. J. Smith
Curtin University	A/Prof. J. Low
University of Western Sydney	Prof. J. Nowotny
Deakin University of Technology	Prof. Y. Chen
University of Western Australia	Prof R. Stamps
Swinburne University of Technology	Prof. C. Berndt, A/Prof. X. S. Gan, Prof. M. Gu

Materials Processing Facilities

- Freeze Drier, Lyph-Loch 4.5, 4.5l/24h
- Spray Drier, GA-32, ~100g/h
- Spray Drier OPD8 3l/hour
- Attrition Mill, 01-HD, 0-660rpm
- Planetary Mill, pulverisette 5, 0-300rpm agate
- Drawing Bench, 8m, fixed die, 11.5kW
- High energy ring mill
- Ultrasonic spray unit
- Bull Block, 22cm diameter
- Rolling mill, 2 x 60mm flat & square rollers, 5cm/s
- Rolling mill, 2 x 55mm supported rollers, 5cm/s
- Swagging machine, 15-1mm diameter
- Hydraulic press, 10t-100t
- More than 30 various furnaces
- Four mirror floating zone single crystal growth
- Controlled atmosphere glove boxes

Thin Film Deposition and Structuring Facilities

- Excimer laser, ComPex301, 9W, 10Hz, 248nm
- Solid state laser, Quanta-Ray, Nd:YAG laser, 200-400 mJ, 266-532 nm, 10Hz
- Thin Films Pulsed-Laser Deposition (PLD) Chamber, 18" With high vacuum system
- Ultra High Vacuum (UHV) PLD chamber equipped with ISD and IBAD.
- UHV chamber (10^{-12} mBar) with multi-target RF magnetron sputtering and multi-pocket electron beam evaporation EBE techniques with direct HV connection to UHV analysis chamber.
- Electron Beam Lithography (EBL) system on the base of SEM (LaB6).
- Optical lithography.

Materials Characterisation

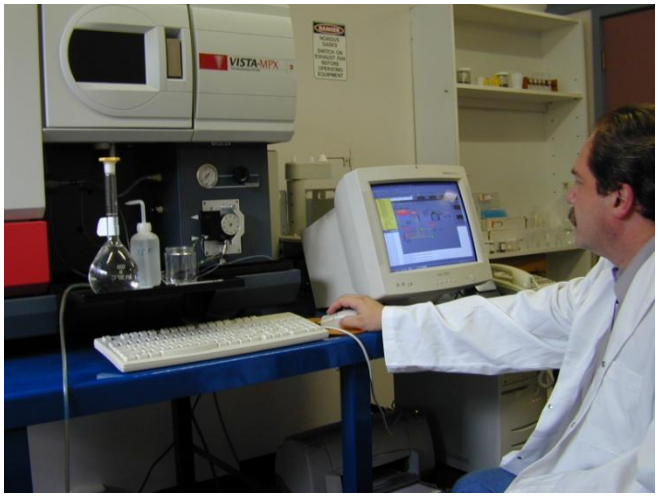
- DTA/TG, Setaram, 18-92, 1750°C
- Mettler Toledo DTA/TGA system, 1600 ºC
- TEM, J2000FX1, with EDS
- Gas absorption analyser Nova 1000 for BET and pore size analyses
- XRD, M18XHFCu with HT 2000°C camera
- XRD, GBC MMA with solid detector for fast and accurate reading of reflections.
- XPS, AES, ISS, UVPS in UHV analysis chamber connected to UHV thin film deposition chamber.
- SEM (LaB6 filament) JEOL, equipped with EDS
- SEM, Stereoscan 440, with EDS and EBSP
- AFM, Nanoscope IIIa
- Particle Size Analyser, Mastersizer S, 0.05-900μm
- XRD, PW1050, 3kW;
- DSC, TA300,-170°C+600°C

Physical Property Characterisation

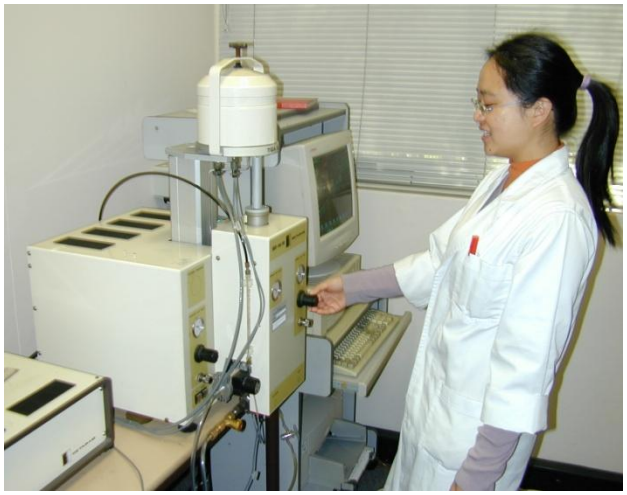
- MPMS, 1.5-400K, 0-5T DC field
- PPMS, 4-400K, 0-9T DC field
- PPMS, 4-1000K (VSM), 0-14T DC field (multiple options such as thermal transport, heat capacity, AC transport are available)
- Horizontal field superconducting Magnet, 0-8T, 5-300K
- 15T VTI magnet, 200A DC current leads for critical current measurements
- Lock-in Amplifier, SR510; Lock-in Amplifier, SR830DSP, 2 x PAR 5209 Lock-in Amplifier, PAR 124 Lock-in Amplifier
- Magneto Optical Imaging, 2K-300K, up to 0.2 T DC field
- Five power supplies (HP and Keithley) 0-900A
- Cryogenic Temperature Controller, ITC4, 0-500K
- SR560 low-noise preamplifier
- Pacific Power 3120 AMXoc current source, 12 kVA
- Spectrometers, Bomem DA3 - fast scan interferometer, Polytec FIR 25 (modified) - slow scan interferometer, Beckman FS 720 - slow scan interferometer, SPEX 1402 double grating 1 m instrument, SPEX 1704 single grating 1 m instrument, 2xSPEX 1870 single grating 0.5 m instruments
- Ballantine 1620 transconductance amplifier (up to 100A)
- Magnets, Oxford Instruments superconducting (0-7T), 2x4 inch iron-cored, Rawson-Lush gaussmeter
- Cantilever (torque force) magnetometer
- Various multimeters, HP and Keithley, including a nano-voltmeter
- VSM, Maglab, 2-400K, 0-12T DC field CTI 8001/8300 cryocooler
- Function Generator, DSC340; Digital Oscilloscope, TDS320
- Digital Teslameter, DTM-132, with Hall Probe; Fluxmeter, 916
- 2 x He Recovery System, 2 He liquefiers from CryoMech – 20 LHe/day each
- Eddy current generator
- Electromagnet, 3473-70, 2T, 150mm pole diameter, Rawson-Lush Gaussmeter
- Lasers, Spectra Physics Model 2040 25 W Ar^+, Spectra Physics Model 165 6 W Ar^+, Spectra Physics Model 3900 Titanium-sapphire, Spectra Physics Model 380 Dye, Spectra Physics 15 mW HeNe
- Detectors, 4xInfrared Laboratories bolometers, Infrared Laboratories Ga-doped Ge photoconductor, N. Coast Scient. Corp Ge photoconductor, Photomultiplier with GaAs photo-cathode
- Cryostats, A number of L He with optical access, L N cryostats, 60 L He storage, 30 L He storage, 60 L N storage, 50 L N storage, 2x30 L N storage, 25 L N storage
- Leak detector Vacuum system

Electro-Chemical Property Characterisation

- Cyclic Voltammograph, BAS CV-27
- Impedance Analyser, M6310
- 4 Channels Data Collection System, MacLab/4e
- ICP-OES, 167-785nm range 0.009nm resolution 200nm
- Scanning Potentiostat, M326; Potentiostat, M363
- Power Supply, DCS 20-50, 0-20V, 0-50A 8 Channels Data Collection System, MacLab/8
- Amplifiers, PAR 124A Lock-in, 2xPAR 5209 Lock-in, Stanford Research SR510
- CHI 660B Electrochemical Workstation
- Arbin MSTAT8000 Electrochemical Workstation
- Automatic PCT Measuring System

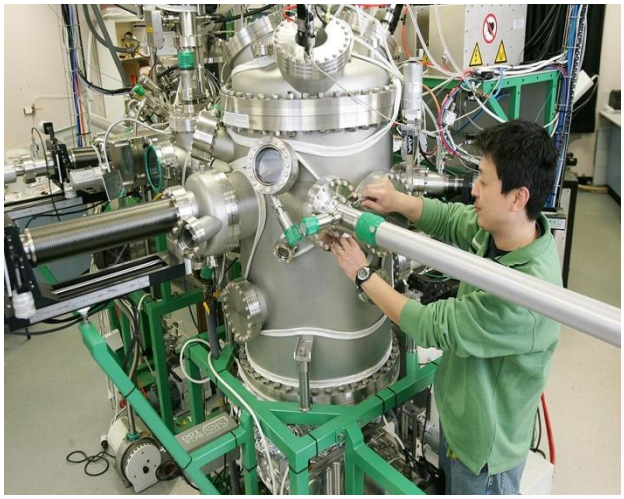


ICP-OES, Vista Simultaneous
Axial Spectrometer



Setaram high-temperature DTA/TGA instrument

Magnetic Property Measurement System
4K-300K, 0-5T



Electron Beam Evaporation Facility

High-resolution JEOL SEM/EBL system

Glove box for controller atmosphere environment

Refereed Publications

Scholarly books:

1. **O. V. Shcherbakova, A. V. Pan, S. X. Dou,** "Magnesium diboride superconductors: development and properties", Published by VDM Verlag Dr. Muller Aktiengesellschaft & Co. KG (2009).

Refereed Journal Articles:

1. **E. Babic, M. Jercinovic, J. H. Kim, and S. X. Dou,** "Vortex pinning in CNT-doped MgB_2 superconductor", *Optoelectrics and Advanced Materials – Symposia* **1**(3), 455 (2009). (IF: 0.451)

2. **C. Z. Chen, C. B. Cai, L. Peng, B. Gao, F. Fan, Z. Y. Liu, M. Lu, R. Zeng, and S. X. Dou "**Flux pinning of stress-induced magnetic inhomogeneity in the bilayers of $YBa_2Cu_3O_{7-delta}/La_{0.67}Sr_{0.33}MnO_{3-delta}$", *Journal of Applied Physics* **106**, 093902 (2009)**.** (IF: 2.072)

3. **J. Chen, J. Z. Wang, A. I. Minett, Y. Liu, C. Lynam, H. K. Liu, and G. G. Wallace**, "Carbon nanotube network modified carbon fibre paper for Li-ion batteries", *Energy & Environmental Science* **2**(4), 393 (2009). (IF: N/A)

4. **M. Chen, J. Zang, D. Q. Xiao, C. Zhang, and F. Liu,** "Nanopumping molecules via a carbon nanotube", *Nano Research* **2**(12), 938 (2009). (IF: 4.370)

5. **S. K. Chen, X. Xu, J. H. Kim, S. X. Dou, and J. L. MacManus-Driscoll,** "Determination of the relative influences of carbon doping and disorder on field and temperature dependent critical current density of MgB_2", *Superconductor Science & Technology* **22(**12), 125005 (2009). (IF: 2.694)

6. **S. Y. Chew, S. H. Ng, J. Z. Wang, P. Novak, F. Krumeich, S. L. Chou, J. Chen, and H. K. Liu,** "Flexible free-standing carbon nanotube films for model lithium-ion batteries", *Carbon* **47**(13), 2976 (2009). (IF: 4.504)

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8. **S. L. Chou, J. Z. Wang, C. Zhong, M. M. Rahman, H. K. Liu, and S. X. Dou,** "A facile route to carbon-coated SnO_2 nanoparticles combined with a new binder for enhanced cyclability of Li-ion rechargeable batteries", *Electrochimica Acta* **54**(28), 7519 (2009). (IF: 3.325)

9. **S. L. Chou,** "High precision charger to investigate spinel $Li_{1+x}Mn_{2-x}O_4$ at elevated temperatures", *ECS 2009 Summer Fellowship Reports*, *Journal of Electrochemical Society - Interface* **18**(4), 58 (2009). (IF: 2.175)

10. **S. L. Chou, J. Z. Wang, H. K. Liu, and S. X. Dou** "SnO_2 meso-scale tubes: One-step, room temperature electrodeposition synthesis and kinetic investigation for lithium storage", *Electrochemistry Communications* **11**(2), 242 (2009). (IF: 4.243)

11. **K. C. Chung, Y. K. Kim, X. L. Wang, and S. X. Dou,** "Texture development of CeO_2 buffer layer and its effect on superconducting MOD-YBCO films", *Journal of the Korean Institute of Metals and Materials* **47**(10), 681 (2009). (IF: N/A)

12. **K. C. Chung, J. M. Yoo, Y. K. Kim, X. L. Wang, and S. X. Dou,** "The effect of water pressure on the texture and morphology of MOD-YBCO films on buffered metal substrates", *Superconductor Science & Technology* **22**(2), 025007 (2009). (IF: 2.694)

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Refereed Conference Articles

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2. **J. H. Ahn, S. Oh, X. L. Wang, and S. X. Dou,** "Infiltration of magnesium in porous boron skeletons", *Proceedings of the Symposium on Superconductors, Electronic and Magnetic Materials,* (Sydney, Australia), *International Journal of Modern Physics B* **23**(17), 3503 (2009). (IF: 0.408)

3. **G. A. Alvarez, X. L. Wang, T. Puzzer, G. Peleckis, and S. X. Dou,** "Spin wave scattering and interface magnetism in superconducting-ferromagnet-superconducting hybrid structures", *Proceedings of the 53rd Annual Conference on Magnetism and Magnetic Materials*, (Austin, TX, USA), *Journal of Applied Physics* **105**, 07E326 (2009). (IF: 2.072)

4. **L. J. Bignell and R. A. Lewis,** "Reflectance studies of candidate THz emitters", *Proceedings of the 2nd International Conference on Optical and Optoelectronic Properties of Materials and Applications*, (London, United Kingdom), *Journal of Materials Science: Materials in Electronics* **20**, S326 (2009). (IF: 1.020)

5. **Z. X. Cheng, X. L. Wang, G. Alvarez, S. X. Dou, S. J. Zhang, and T. R. Shrout,** "Magnetic glassy behaviour in ferroelectric relaxor type solid solutions: Magnetoelectric relaxor", *Proceedings of the 53rd Annual Conference on Magnetism and Magnetic Materials*, (Austin, TX, USA), *Journal of Applied Physics* **105**(7), 07D902 (2009). (IF: 2.072)

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8. **H. Kimura, R. Tanahashi, K. Maiwa, H. Baba, Z. X. Cheng, and X. L. Wang,** "Potassium-sodium-rubidium niobate single crystals and electric properties", *Proceedings of the* Symposium on Superconductors, Electronic and Magnetic Materials, (Sydney, Australia), *International Journal of Modern Physics B* **23**(17), 3631 (2009). (IF: 0.408)

9. **R. A. Lewis and R. E. M. Vickers**, "Terahertz magnetospectroscopy of heavily-doped Si(P)", *Proceedings of the 18th International Conference on High Magnetic Fields in Semiconductor*

Physics and Nanotechnology, (Sao Pedro, Brazil), International Journal of Modern Physics B **23**, 2856 (2009). (IF: 0.408)

10. **W. X. Li, R. Zeng, L. Lu, Y. Zhang, S. X. Dou, Y. Li, R. H. Chen, and M. Y. Zhu,** "Improved superconducting properties of in situ powder-in-tube processed $Mg_{1.15}B_2$/Fe wires with nano-size SiC addition", *Proceedings of the 21st International Symposium on Superconductivity*, (Tsukuba, Japan), Physica C-Superconductivity and its Applications **469**(15-20), 1519 (2009). (IF: 0.723)

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17. **S. V. Pysarenko, A. V. Pan, S. Downing, and S. X. Dou,** "Development of multilayer coated conductors with simplified buffer structures", *Proceedings of the Symposium on Superconductors, Electronic and Magnetic Materials*, (Sydney, Australia), International Journal of Modern Physics B **23**(17), 3526 (2009). (IF: 0.408)

18. **M. Ranot, W. K. Seong, S. G. Jung, N. H. Lee, W. N. Kang, J. H. Joo, Y. Zhao, and S. X. Dou,** "Enhancement of the critical current density of MgB_2 thick films by Ag- and Cu-impurity layers", *Proceedings of the 21st International Symposium on Superconductivity*, (Tsukuba, Japan), Physica C: Superconductivity and its Applications **469**(15-20), 1563 (2009). (IF: 0.723)

19. **J. L. Wang, S. J. Campbell, R. Zeng, C. K. Poh, S. X. Dou, and S. J. Kennedy,** "Re-entrant ferromagnet $PrMn_2Ge_{0.8}Si_{1.2}$: Magnetocaloric effect", *Proceedings of the 53rd Annual Conference on Magnetism and Magnetic Materials*, (Austin, TX, USA), *Journal of Applied Physics* **105**(7), 07A909 (2009). (IF: 2.072)

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23. **W. Xu, Z. Zeng, A. R. Wright, C. Zhang, J. Zhang, and T. C. Lu,** "Exchange-induced band hybridization in InAs/GaSb based type II and broken-gap quantum well systems", *Proceedings of the International Conference on Superlattices, Nanostructures and Nanodevices*, (Natal, Brazil), *Microelectronics Journal* **40**(4-5), 809 (2009). (IF: 0.778)

24. **X. Xu, J. H. Kim, Y. Zhang, M. Jercinovic, and E. Babic,** "Critical current density performance of malic acid doped magnesium diboride wires at different operating temperatures", *Proceedings of the Symposium on Superconductors, Electronic and Magnetic Materials*, (Sydney, Australia), *International Journal of Modern Physics B* **23**(17), 3497 (2009). (IF: 0.408)

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27. **Y. Zhang, S. H. Zhou, C. Lu, K. C. Chung, and S. X. Dou,** "Effect of sintering time on superconductivity in MgB_2", *Proceedings of the Symposium on Superconductors, Electronic and Magnetic Materials*, (Sydney, Australia), *International Journal of Modern Physics B* **23**(17), 476 (2009). (IF: 0.408)

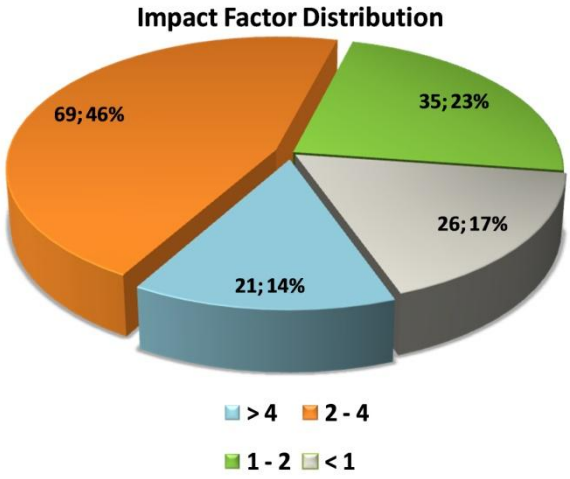
28. **Y. Zhang, S. H. Zhou, W. X. Li, X. L. Wang, and S. X. Dou,** "High critical current density of MgB_2 bulks sintered in flowing welding grade Ar atmosphere", *Proceedings of the Symposium on Superconductors, Electronic and Magnetic Materials*, (Sydney, Australia), *Internal Journal of Modern Physics B* **23**(17), 3538 (2009). (IF: 0.408)

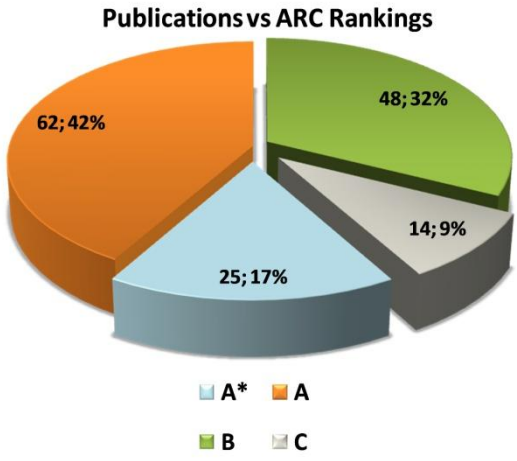
29. **Z. Z. Zhu, Y. Li, M. Y. Zhu, H. M. Jin, X. L. Deng, Z. Wang, H. K. Liu,** "Hydrothermal synthesis of nanocrystal MnO_2 under pulsed magnetic field", *Proceedings of the Symposium on Superconductors, Electronic and Magnetic Materials*, (Sydney, Australia), *International Journal of Modern Physics B* **23**(17), 3608 (2009). (IF: 0.408)

Conference Publications

1. **E. Constable, Y. Hu, J. Horvat and R. A. Lewis** "The Emission of visible radiation by peeling adhesive tape", *Proceedings of the 33rd Annual Condensed Matter and Materials Meeting*, Wagga Wagga, Australia (2009).
2. **S. Hargreaves and R. A. Lewis,** "Ultrafast interactions in condensed matter as source of terahertz-frequency electromagnetic radiation", *Proceedings of the* 33rd *Condensed Matter and Materials Meeting*, Wagga Wagga, Australia (2009).
3. **J. C. Knott and R. A. Lewis,** "Studies of the electroresistive properties of electronic oxides", *Proceedings of the 33rd Condensed Matter and Materials Meeting*, Wagga Wagga, Australia (2009).
4. **K. Radhanpura, S. Hargreaves and R. A. Lewis**, "The generation of terahertz frequency radiation by optical rectification", *Proceedings of the 33rd Condensed Matter and Materials Meeting*, Wagga Wagga, Australia (2009).
5. **R. A. Lewis,** "Terahertz generation by optical rectification of GaAs and related materials", *Proceedings of the International Conference on Lasers and Optical Electronics Pacific Rim*, Shanghai, China (2009).
6. **R. A. Lewis,** "Generation of terahertz radiation by excitation of GaBiAs by near-infrared femtosecond pulses", *Proceedings of the Australasian Conference on Optics, Lasers and Spectroscopy and Australian Conference on Optical Fibre Technology*, Adelaide, Australia (2009)

Publication Statistics





Australian Research Council Grants

ARC Centre of Excellence Grants

Chief Investigators	Title	2009 Funding
H. K. Liu	Nano-materials for energy storage	$230,000
	Total	**$230,000**

ARC Discovery Scheme Grants

Chief Investigators	Title	2009 Funding
X. L. Wang	Exploration for new materials for spintronics	$120,000
S. X. Dou, J. Driscoll, R. L. Flukiger, H. Kumakura, M. D. Sumption	Current limiting mechanisms in magnesium diboride superconductors	$390,000
G. X. Wang, C. Zhang, K. K. Konstantinov, J. Z. Wang, M. S. Islam, R. S. Liu, P. Novak, P. H. Notten	First principles for development of novel hybrid electrochemical energy storage and conversion systems	$220,000
Z. P. Guo	Charge transfer mechanism in 3-dimensional pore-solid nanoarchitectures for electrochemical systems	$100,000
Z. P. Guo, H. K. Liu, P. H. Notten, J. Chen, A. Zuettel	New concepts with multidisciplinary approach: novel functionalised nanostructures for hydrogen storage	$100,000
G. Peleckis	Development of novel high efficiency thermoelectric oxides for high temperature power generation	$35,000
S. H. Zhou	Fabrication of high quality MgB_2 superconductor	$40,000
S. X. Dou, J. H. Kim, T. H. Johansen, E. Bruck	Giant magnetocaloric materials and room temperature refrigeration	$210,000
X.B. Yu	Improvement and synthesis of advanced hydrogen storage materials for fuel cell application	$96,000
C. Zhang, D. Li, F. Liu, R. B. Kaner, Y. Jiang	Novel graphene nanostructures: modelling, synthesis, fabrication and characterization	$145,000
A. V. Pan, C. P. Foley, T. H. Johansen, H. Hilgenkamp	Tailoring superconducting hybrid multilayered film systems for electric and electronic applications	$164,000
X. L. Wang, Z. X. Cheng, D. P. Chen, T. Kimura, F. Klose	Frustrated magnets: a new platform for multiferroic materials	$160,000

R. A. Lewis, J. Horvat, W. Xu	Better emitters, enhanced optics, superior detectors: advancing terahertz science and technology for applications in medicine, agriculture, industry and national security	$120,000
J. Z. Wang	Development of inorganic-conducting polymer composites and ionic liquid based electrolytes for rechargeable lithium batteries	$110,000
	Total	**$2,010,000**

ARC Linkage Projects

Chief Investigators	Title	2009 Funding
S. X. Dou, A. V. Pan, D. Q. Shi, R. Taylor, J. Barry, T. Yamashita	Development of high performance second generation superconductors	$90,000
G. X. Wang, H. K. Liu, K. K. Konstantinov, J. Z. Wang, D. Wexler, O. Savadogo	Exploration of new catalyst materials for hydrogen/air fed proton exchange membrane fuel cells	$90,000
Z. P. Guo, H. K. Liu, J. Z. Wang, K. K. Konstantinov, M. Forsyth	Miniature lithium ion battery for implantable medical device applications	$100,000
A. V. Pan, S. X. Dou, O. Mukhanov	Development of superconducting leads with ultra-low thermal conductivity for cryoelectronic applications	$141,000
C. Zhang, X. L. Wang, G. X. Wang, T. Toyoda	Novel methods for enhancing room temperature figure of merit of thermoelectric/thermionic materials for refrigeration applications	$79,000
Z. P. Guo, H. K. Liu, C. D. Cook, D. Wexler, H. Zhu, X. J. Zhu	Development of advanced lithium ion battery and battery management system for electric/hybrid electric vehicle applications	$40,000
S. X. Dou, X. L. Wang, C. D. Cook, X. Xu, E. W. Collings, J. Yoo	Magnesium diboride superconductor magnets for applications	$100,000
G. X. Wang, D. Wexler, J. Horvat, C. Zhang, H. Kim	Novel lithium iron based olivine phosphates as cathode materials for the development of new generation power batteries	$125,000
	Total	**$765,000**

ARC Linkage International Awards/Fellowships

Chief Investigators	Title	2009 Funding
R. A. Lewis, R. Mendis, R. E. M. Vickers	Advanced materials and structures for terahertz science and technology	$10,000
S.X Dou, Y. Zhao, X. Xi, G. Ramanath, Q.J. Li, G. Peleckis	Approved development of nano-structured thermoelectric materials for power generation from heat	$20,000

X. L. Wang, S. Lee	Mechanism and enhancement of supercurrent carrying ability in magnesium diboride superconductor	$18,000
J. H. Kim, S. X. Dou, G. Hong	Study on the deposition of superconducting REBCO film via chemical route for coated conductor	$143,000
A. V. Pan, T. Johansen	Magnetic walls as nano-manipulators for physics, bio- and medical technologies	$71,000
	Total	**$262,000**

2009 Australian Research Council Grants Total: $3,037,000

Non-ARC Grants

National Hydrogen Materials Alliance, CSIRO Flagship Grant:

Chief Investigators	Title	2009 Funding
H. K. Liu	Carbon-based and Mg based Hydrogen Materials	$50,000
	Total	**$50,000**

DIISR International Science Linkage Projects

Chief Investigators	Title	2009 Funding
C. Zhang, R. A. Lewis, X. L. Wang, D. Li	High performance nanomaterials for thermionics and thermoelectric applications	$85,000
C. Zhang, R. A. Lewis, J. Horvat, R. Vickers, W. Xu, J. Xi	Development of terahertz emitters based on electronic and hybrid spintronic materials	$50,000
	Total	**$135,000**

URC Small Grants & ARC Near-Miss Grants

Chief Investigators	Title	2009 Funding
J. H. Kim, Y. Zhao	The evolution of solar energy in photoelectrochemical cells using nano-materials	$12,000
Z. P. Guo	Exploration of novel highly effective electrocatalysts for proton exchange membrane fuel cells	$14,000
J. Horvat	Synthesis of $ZnCr_2Se_4$ nanoparticles	$14,000
G. Peleckis, A. Mozer, D. P. Chen	Titanium dioxide 101: characterization and utilization of well defined single crystal TiO2/dye surfaces for solar energy conversion	$14,000
	Total	**$54,000**

UOW Support (Performance, Management, PGS Maintenance) **$302,000**

2009 Grand Total Funding $3,808,000

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