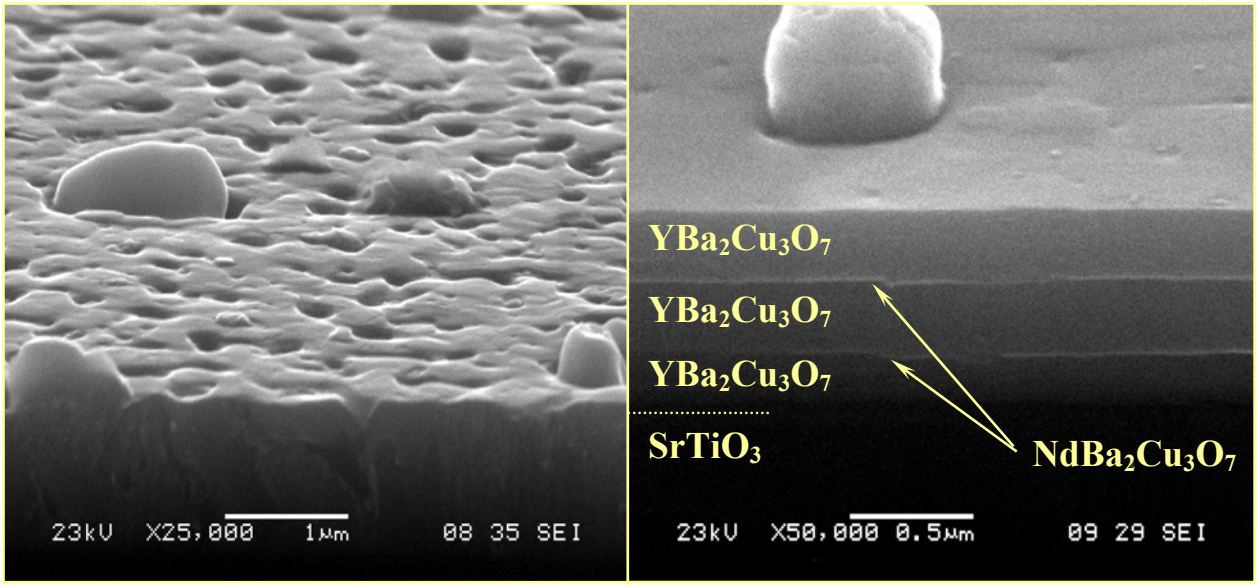
Institute for Superconducting & Electronic Materials



Annual Report 2005

University of Wollongong

Contents

Cover picture: *The image on the front page shows two surfaces of $YBa_2Cu_3O_7$ film (left) and $YBa_2Cu_3O_7/NdBa_2Cu_3O_7$ multilayer (right) of the same 1 micrometer thickness observed by scanning electron microscopy, presented at European Conference on Applied Superconductivity 2005 in Vienna, Austria, and published in Applied Physics Letters by A. V. Pan, S. Pysarenko, and S. X. Dou.*

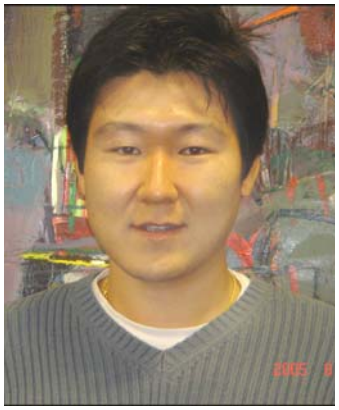
ISEM Postgraduate Student Awards

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.

Postgraduate Student Excellence Award 2005

Serhiy Pysarenko

Postgraduate Student Merit Award 2005



Min Sik Park

Mission Statement

Establish and maintain a world-class co-operative research team in superconducting and electronic materials science and technology and stimulate the technological and commercial development of Australian Industry in this field.

Professor SX Dou
Director
e-mail: shi_dou@uow.edu.au

Prof Chao Zhang
Associate Director
e-mail: chao_zhang@uow.edu.au

Ms Joy de Mestre
Administration Officer
e-mail: Joy@uow.edu.au

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Facsimile: 61 + 2 4221 5731
web site: http://www.uow.edu.au/eng/ISEM

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Wollongong NSW 2522
Australia

Applied Superconductivity

Dr. J Horvat
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e-mail: jhorvat@uow.edu.au

Spintronic & Electronic Materials

Dr. X.L. Wang
Telephone: 61 + 2 4221 5766
Facsimile: 61 + 2 4221 5731
e-mail: xiaolin@uow.edu.au

Energy Materials

Prof. H.K.Liu
Telephone: 61 + 2 4221 4547
Facsimile: 61 + 2 4221 5731
e-mail: hua_liu@uow.edu.au

Dr. G.X. Wang
Telephone: 61 + 2 4221 5726
Facsimile: 61 + 2 4221 5731
e-mail: gwang@uow.edu.au

Thin Film Technology

Dr A.V.Pan
Telephone: 61 + 2 4221 4729
Facsimile: 61 + 2 4221 5731
e-mail: pan@uow.edu.au

Nanostructured Materials

Dr. K. Konstantinov
Telephone: 61 + 2 4221 5765
Facsimile: 61 + 2 4221 5731
e-mail: kostan@uow.edu.au

Terahertz Science, Thermionics & Solid State Physics

Prof. C. Zhang
Telephone: 61 + 2 4221 3458
Facsimile: 61 + 2 4221 5944
e-mail: chao_zhang@uow.edu.au

Director's Report

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

2005 is the second year of the Three Year Plan (2004-2006) of the University's Research Strength Program, which has identified the Institute for Superconducting and Electronic Materials (ISEM) as one of the key research strength areas. Our numerical target for the three years was ten ARC fellows, twenty full time researchers, forty postgraduate students enrolled, 50% of papers published in journals with an impact factor greater than 2 and $2m ARC fund per year. Our 2005 results have almost all surpassed these targets. ISEM has ten various ARC fellows, nineteen full time researchers, and thirty one PGS enrolled; there was a total of 78 publications and half of the regular articles were published in journals with impact factors greater than 2. The total ARC funding obtained in the 2005 round exceeded $2.5 million.

Major progresses have been made in several of our key research areas. In energy storage research, we further developed nanocrystalline transition metal and oxides for lithium storage and PEO based polymer electrolyte. Silicon/disordered carbon (Si-DC) nanocomposites have been developed and synthesised for energy storage applications. By studying the thermal stability and hydrogen storage property of $Mg_{1.9}Cu_{0.1}Ni_x$ we found the thermal stability of the as-prepared alloys, the hydrogenation ability and desorption kinetics are closely related with the nickel content. MgH_2-carbon composites for hydrogen storage have been synthesised by controlled reactive mechanical ball milling of carbon allotropes and magnesium in hydrogen. The rehydrogenated composite containing graphite shows a distinguished decrease in the desorption temperature In superconductor technology, a new approach to the simultaneous improvement of surface smoothness and critical current density (J_c) enhancement in $YBa_2Cu_3O_7$ films has been developed by introducing nano-multilayered $(Y/Nd)Ba_2Cu_3O_7$ structure. This technology allows us to deposit thick films which have smoother surface structure and outperform current-carrying ability of the thin monolayer films. Our research on nanoparticle doped MgB_2 has shown a much improved $J_c(H)$, opening up new avenues for technology development. Nano-dopants containing carbon (SiC, C-nanotubes) improve both, vortex pinning and upper critical field. Nano-SiC gives the strongest improvement of $J_c(H)$. In spintronic, many transparent oxide diluted magnetic semiconductors have been discovered and systematically studied by Rietfield refinement, transport, and magnetic measurements, and synchrotron radiation. We have successfully synthesised and systematically studied a series of two dimensional novel cobalt magnetic oxides. These materials will play key roles in the development of spintronic materials and devices. A new transport mechanism has been discovered. Our theoretical and numerical results predicted a non-dissipative transverse electric current in the absence of applied magnetic field. In terahertz optoelectronics, we have obtained time-domain and frequency-domain spectra which lay the foundation for the research in nonlinear optics and imaging. New emission mechanisms based on plasma emission has been investigated. We have expanded our research on nanomaterials based thermionics to the areas of Si-based systems and energy-selective quantum structures.

2005 is a good year in our staff development; our staff remains proactive in their research and career development. Dr. Xiaolin Wang had another successful year in research, achieving several important results in spintronic materials development. Dr. Rodney Vickers made a major contribution to the development of terahertz laboratory and played a key role in faculty education program. Both Dr. Wang and Dr. Vickers were promoted to associate professor at the end of 2005. Dr. Pin Lyu was appointed as research fellow on ARC projects to study the nanomaterials based thermionics. A number of visiting researchers and internship students spent extended time at ISEM carrying out collaborative research, including the following visiting

staff: Prof. V. M. Pan from Institute for Metal Physics (Kiev, Ukraine), Dr. E. Collings from Ohio State University (USA), Prof. Z.S. Ma from Peking University, C. H. Yang from Institute of Solid State Physics, Chinese Academy of Sciences, D. Santos from UNESP Sao Paolo State University, Dr. J.M. Yoo, ARC International Professional Fellow, the Group leader of HTS wire lab in Korea Institute of Machinery and Materials, Dr. S. Soltanian, PVC from University of Kurdistan, Sanandaj, Iran. Prof. J-H. Ahn from the Andong National University, Dr. S. Zhong from Guangzhou Delong Energy Ltd, Dr. X. F. Gao from Lexcel Battery Ltd, Mr. J.F. Wu from DLN battery Ltd, and Prof. Z-F. Ma from Shanghai Jiao Tong University.

Our institute made very successful ARC grant bids in the 2005 round with a total of $2,519,000 awarded, including a battery program in the ARC Centre for Electromaterials Sciences (H. K. Liu), four Discovery Projects (Y. Zhao ; X. L. Wang/Z Cheng ; D. Shi and R. A. Lewis), an ARC fellow (Y. Zhao), one Linkage Infrastructure Project (R. A. Lewis/R. Vickers,/R. Mendis); and two International Linkage Projects (C. Zhang/D. Abbott and MJ Qin/SY Ding).

Our postgraduate students have made significant progress on their degree programs. Shokat Keshavarzi was awarded a PhD degree, and Qiwen Yao, a Master's degree. Q. Yao is now working on his PhD thesis at ISEM and Shokat Keshavarzi is now on academic staff at Shahrekord University, Iran. S. Pysarenko won the Excellent Postgraduate Student Award for 2005; Min Sik Park won the Merit Award in 2005. X. Xu and M.S. Al Hossain were awarded an APAI scholarship, B. Winton, and M. Park won ISEM and matching scholarships. We congratulate all our new postgraduate students on their success and welcome them to our institute.

Our laboratory infrastructure has been substantially improved during 2005. An Ultra High Vacuum (UHV) multi-purpose pulsed laser deposition (PLD) chamber with an incorporated ion gun for ion-beam assisted deposition (IBAD) and a possibility to carry out inclined substrate deposition (ISD) process has almost been completed. This chamber is also equipped with a multi-target holder and large rotating substrate heater/holder, as well as with a control instrument rack for the automated control of the PLD chamber. A Dektak Surface Profiler 6M for films thickness measurements and structural characterisation has been installed after the successful application for RIBG Pool 2 university grant. The nano-multilayer fabrication facilities have all been installed. These include Electron Beam Evaporator (EBE) and Magnetron Sputtering units integrated with an ultra-high vacuum chamber, a surface analysis unit including XPS, Auger, UPS and ISS, a high performance JEOL SEM with LaB6 gun, EDX and BSC (backscattered detectors), and an Electron Beam Lithography (EBL) unit. These facilities were funded through the Systemic Infrastructure Initiative scheme by DIST with total funding of $1.7 million for three years and are supported by 13 institutions around Australia. These facilities will enhance the capability for nano-multilayer fabrication at ISEM. The terahertz facility of the solid state group at ISEM is now operational and will be further expanded by a second ARC linkage-infrastructure grant.

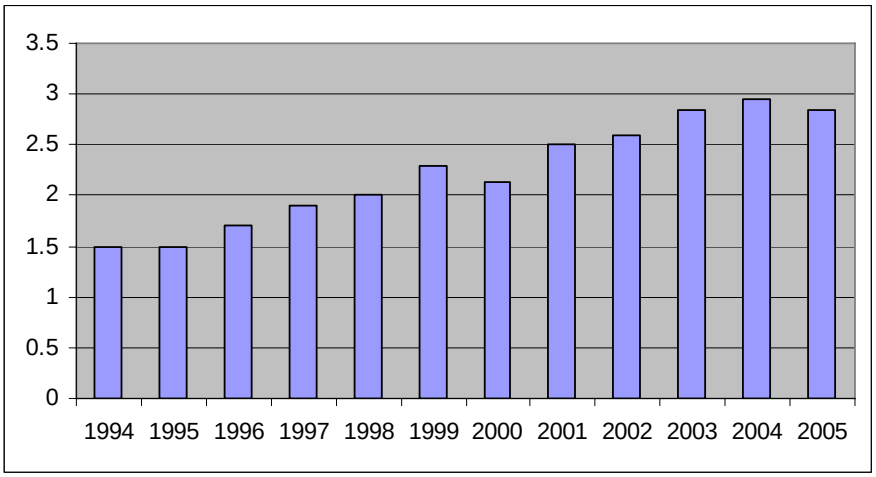
The university will be constructing a new state-of-the-art building on the Innovation Campus to house two institutes, our institute and IPRI which will bring together all our staff, students and advanced materials equipment into one location. URC will be contributing $20M towards the construction of these facilities plus an additional $5M in equipment for the two institutes. Our institute will truly be a world-class materials research establishment by 2007.

S X Dou

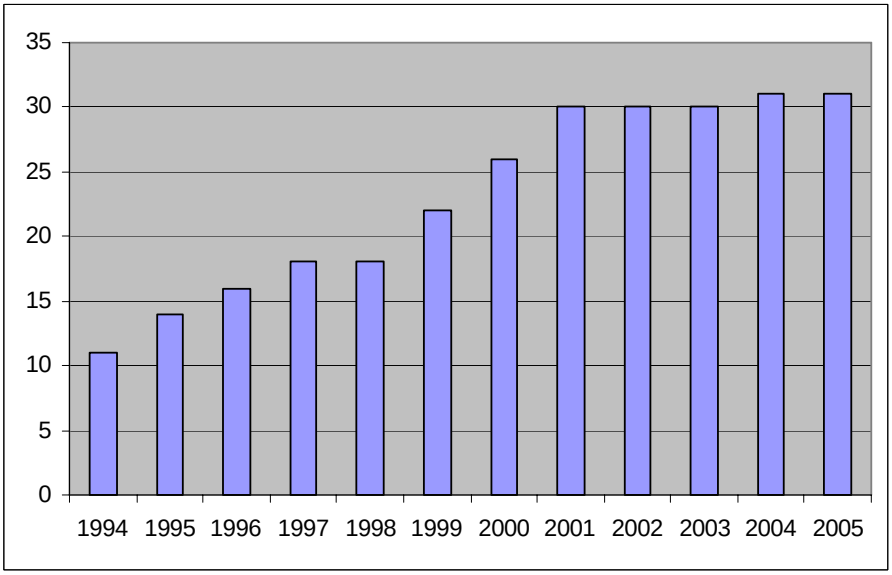
Shi Xue DOU

Director

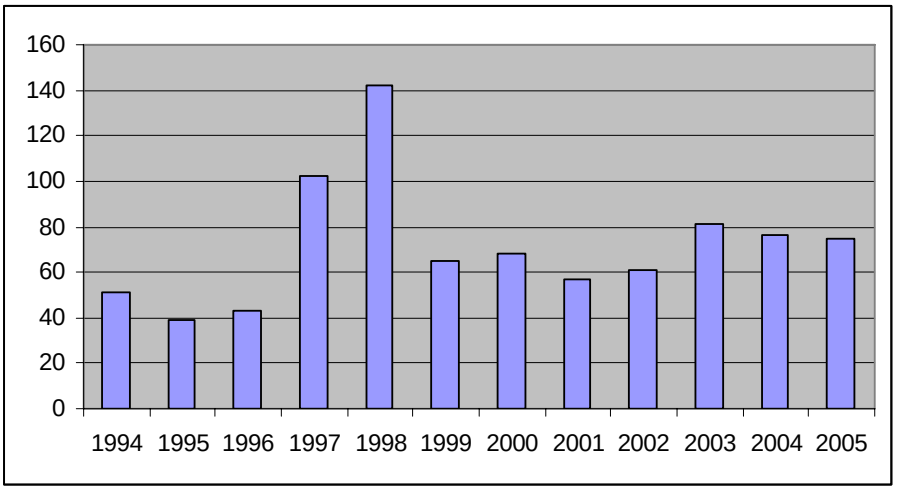
Research Grant Funds ($M)



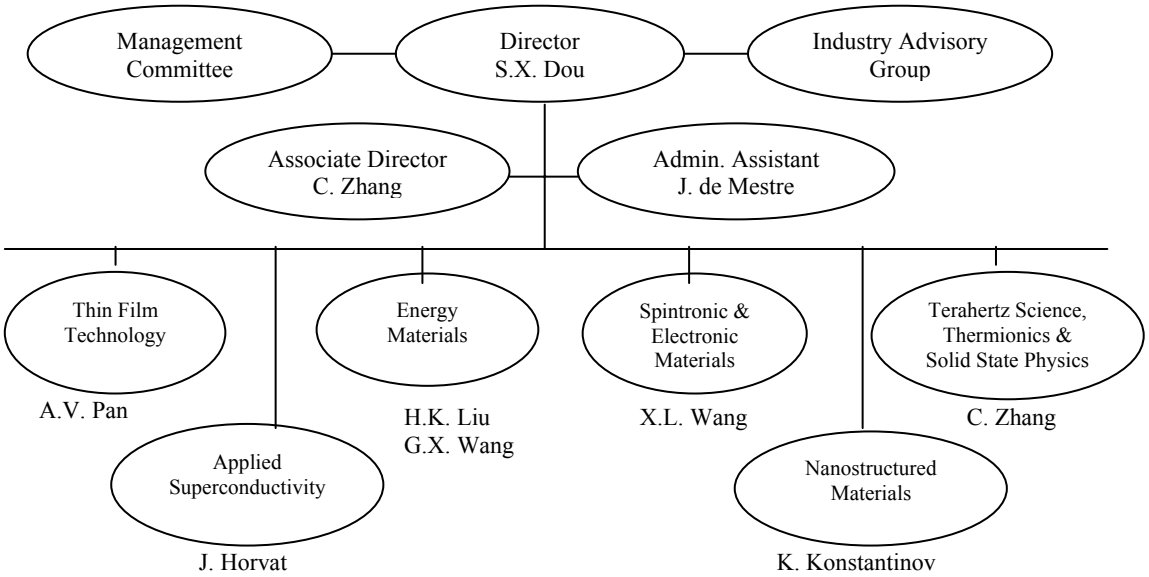
Postgraduate Student Numbers



Refereed Publications (DETYA Categories)



Management 2005



Management Committee

Chairperson:	Prof. M. Sheil	Pro Vice Chancellor, UoW
	Prof. S.X. Dou	Director, ISEM
	Prof. C. Cook	Dean, Faculty of Engineering, UoW
	Prof. C. Zhang	Associate Director, ISEM
	Prof. H.K. Liu	Research Co-Coordinator, ISEM

Industry Advisory Group

Dr T. Beales	Manager	Australian Superconductors Ltd, Metal Manufactures Ltd
Mr B. Buchtmann	Advanced System Engineer	Email Limited
Mr. P.W. Dowling	Managing Director	Polarised Technologies Pty Ltd
Dr. X.F. Gao	General Manager	Lexel Batteries Co. Ltd, Shenzhen, PR China
Mr R. Neale	Managing Director	Alphatech International Ltd
Mr M. Tomsic	Managing Director	Hyper Tech Research Ltd, Ohio, USA,
Prof J.S. Wang	President	Taiyi Battery Co. Ltd., Zhuhai, PR China
Mr J.F. Wu	Marketing Manager	DLG Battery Co Ltd, Shenzhen, P.R. China
Dr. S. Zhong	Managing Director	Guangzhou Delong Energy Technology, Guangzhou P.R. China

Personnel

Director
Prof. S.X. Dou, Dipl, PhD, DSc, FTSE

Associate Director
Prof. C. Zhang, BSc, PhD, MA, MPhil, FAIP

Senior Program Co-Coordinators

Prof. T. Beales, BSc, PhD MM/UoW Consortium Manager

Prof. H.K.Liu, Dipl. for PGS, APF.

Prof. C. Zhang, BSc, PhD, MA, MPhil, FAIP

Dr. J. Horvat, BSc, PhD

Dr. X.L. Wang, BSc, MSc, PhD,
ARC QE-II Fellow

Dr. M. Ionescu, BSc, MSc, PhD

Dr. K. Konstantinov, BSc, MSc, PhD

Dr. A.V. Pan, MSc, PhD,
ARC postdoctoral Fellow

ARC Fellows

Prof. J.H. Ahn, Assoc. Professorial Fellow

Prof. S.X. Dou, Dipl, PhD, DSc, FTSE,
Australian Professorial Fellow

Dr. Z.P. Guo, BSc, MSc, PhD,
Australian Postdoctoral Fellow

Prof. H.K. Liu, Dipl. For PGS, Dipl. AQC,
Australian Professorial Fellow

Dr. A.V. Pan, MSc, PhD,
ARC postdoctoral Fellow

Dr G.X. Wang, BSc, MSc, PhD,
ARC Postdoctoral Fellow

Dr. J. Wang, BSc, MSc, PhD,
ARC Postdoctoral Fellow

Dr. X.L. Wang, BSc, MSc, PhD,
ARC QE-II Fellow

Prof. J.Y. Lee, ARC International Prof. Fellow

Dr. S. H. Zhou. BSc, MSc, PhD,
ARC Postdoctoral Fellow

Prof. J. M. Yoo, BSc, MSc, PhD,
ARC International Professorial Fellow

Research Staff

Dr. Z. Cheng, BSc, MSc, PhD

Dr. F. Gao, BSc, PhD

Dr. M.J. Qin, BSc, MSc, PhD

Dr. T. Silver, BSc, PhD

Dr. D. H. Wilke, BSc, PhD

Dr. J. H. Kim, BSc, PhD

Dr. R. Zeng, BSc, MSc, PhD

Dr. D. Q. Shi, Bsc, Msc, PhD

Dr. R. Mendis, BSc, PhD

Dr. S. Shrestha

Dr. P. Lyu, BSc, PhD

Academic Staff

Prof. C. Cook, BSc, PhD, FIE Aust

Prof. D. Dunne, BSc, PhD, FIE Aust

Dr. C. Freeth, MSc, PhD, MAIP

Prof. R. A. Lewis, BSc (Hons), PhD, FAIP, FRMS

Dr. A.D. Martin, MSc, PhD, MAIP

Assoc. Prof. R.E.M. Vickers, MSc, PhD, MAIP

Prof. P. Fisher, BSc, PhD

Visiting Staff

Prof. E.W. Collings, Ohio State University

Prof. H. Liu, Sichuan Uni, PR China

Dr. S. Kennedy, ANSTO

Dr. S. Zhong, Delong Energy Technology, China

Prof. J. Chan, Nankai University, PR China

Dr. G. Alvarez

Prof. S. Y. Ding, Nahjing University

Technical Staff

Mr. R. Kinnell

Administration Officer

Ms. Joy de Mestre

Postgraduate Students

Current

PhD	Thesis Title	Supervisors
S Bewlay	Investigation on Li-Co-Ni System for Lithium Ion Batteries	SX Dou, GX Wang
Y Chen	Investigation of Cathode Materials for Li-ion Batteries	HK Liu, GX Wang
M Farhoudi	Synthesis and characterisation of transition material oxide	XL Wang, SX Dou, M. James
D Fisher	Dissipation Effect in Resonant Tunnelling through Double Barrier Structures	C Zhang
ZG Huang	Nano-materials for hydrogen storage	HK Liu, ZP Guo
S.Keshavarzi	Investigation of Vortex Dynamics of $(Tl,Pb)(Sr,Ba)_2Ca_2Cu_3O_y$ and Twinned $Sm_{1+x}Ba_{2-x}Cu_3O_{6+y}$ (x=0.04) Single Crystals	SX Dou, J Horvat MJ Qin
P Lavers	Electronic structure of perovskites	QM Qin, SX Dou
A Li	YBCO thick and thin films	M Ionescu, HK Liu
G Li	Numerical Analysis of Electromagnetic Behaviour of High T_c Superconductors in Magnetic Field	HK Liu, MJ Qin
S Needham	Anode and Cathode Materials for Lithium Ion Batteries	GX Wang, HK Liu
SH Ng	Nano-structured Materials for Electrode in Rechargeable Li-ion Battery	HK Liu, JZ Wang
M O'Dwyer	Thermionic Cooling and Power Generation	C Zhang, RA Lewis
Jinsoo Park	Chemical and biological nanosensors	G.X. Wang, H.K. Liu
Min Sik Park	Thin-film microbatteries and semiconductor nanowires	H.K. Liu, S.X. Dou, and G.X. Wang,
G Peleckis	Spintronic Materials	XL Wang, SX Dou
SH Pilehrood	Electronic Properties of Semiconductor Nanostructures under Intense Terahertz Radiation	C Zhang
S Pysarenko	HTS Multi-Layers Thin Films Fabrication	AV Pan, SX Dou
M Roussel	Critical Current Density and Flux Pinning in HTS	AV Pan, SX Dou

PhD	Thesis Title	Supervisors
O Sherbakova	Two-Gap Superconductors	SX Dou, MJ Qin
M Smith	T Ray Spectroscopy	RA Lewis, C Zhang R Vickers
B Winton	An Investigation of the Surfaces of Biomaterials	SX Dou, M Ionescu R. Vickers
X Xu	Study of Multi-layer Coated Superconductors	SX Dou, MJ Qin
J Yao	Thin film microbattery	K. Konstantinov H.K. Liu
Q Yao	Studies of novel two dimensional cobalt oxides perovskite	XL Wang, SX Dou
WK Yeoh	Control of Nanostructure for Enhancing Superconductor Performance through Chemical Doping	SX Dou, J Horvat
L Yuan	Nano-materials for use in Li-ion Batteries	HK Liu K Konstantinov GX Wang
Y Zhang	Effect of nano Ti doping in MgB_2	S.X. Dou, A. Pan
Y Zhao	Fabrication and Characterisation of MgB_2 Films	SX Dou, M Ionescu
ZW Zhao	Novel Carbon Supported Pt and Pt alloy Catalysts for Proton Exchange Membrane Fuel Cells and Direct Methanol Fuel Cells	HK Liu, ZP Guo

Master's	Thesis Title	Supervisors
K de Silva	Diamond Growth	SX Dou, AV Pan
ZJ Lao	New Materials for Supercapacitors	K Konstantinov GX Wang

Completions

PhD Name & Thesis Title	Awarded	Position	When Appointed
M Apperley The Fabrication of High T_c Superconductor Wire	1992	Chief Technologist Australian Superconductors Business development manager University of Sydney	1993 2004
R Baker Zeeman and Piezospectroscopy of Antimony and Aluminium in Germanium	2001	Professional Officer University of Wollongong	2003
A Bourdillion Microstructure, Phase Characterisation and Texture Processing of HTS	1992	Senior Engineer Hewlett Packard, Singapore Hewlett Packard, USA	1993 2000
Jobe Probakar Chelliah Optical spectroscopy of semiconductors	2000		
J Chen High Energy Storage Material for Rechargeable Nickel-Metal Hydride Batteries	1999	NEDO Fellow Osaka National Research Institute Professor Nankai University, China	1999 2002
N Cui Magnesium Based Hydrogen Storage Alloy Anode Materials for Ni-MH Secondary Batteries	1998	Research Fellow Alberta University, Canada Electrochemist Energizer Co, USA	1997 2000
F Darmann Characterisation of melt-texture Y-123 materials		Research Fellow ANSTO	2003
XK Fu Fabrication and Characterisation of Bi-2223 Current Lead	2002	Research Fellow Texas A&M University, USA University of Waterloo, Canada	2002 2005
F Gao Studies on the Synthesis, Characterisation and Properties of Colossal Magnetoresistive (CMR) Materials	2004	Research Assistant ISEM, University of Wollongong	2004
YC Guo Investigation of Silver-clad $(Bi,Pb)_2Sr_2Ca_2Cu_3O_{10-x}$ Superconducting Tapes	1994	STA Fellow Nat. Res. Inst. Of Metals, Japan ARC Postdoctoral Fellow ISEM, University of Wollongong	1997 1998
ZP Guo Investigation on Cathode Materials for Lithium-ion Batteries	2003	ARC Postdoctoral Fellow ISEM, University of Wollongong IT, University of Wollongong	2003 2003
RJ Heron Far-infrared Studies of Semiconductors in Large Magnetic Fields	1998	Postdoctoral Fellow SUNY, Buffalo, USA	1997
QY 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 Research Scientist Argonne National Lab., USA Senior Engineer, Lucent, USA	1997 1999 2001

PhD Name & Thesis Title	Awarded	Position	When Appointed
M Ionescu Growth and Characterisation of Bi-2212 Crystals and Improvement of Bi-2212/Ag Superconducting Tapes	1998	Assistant Director ISEM, University of Wollongong Senior research scientist ANSTO	1994 2004
JX 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 ARC, PDF ISEM, University of Wollongong	1997 2000
Shokat 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
M Lerch Optical & Electrical Studies of Resonant Tunnelling Heterostructure	1998	Research Fellow Medical Physics, University of Wollongong	1999
M Lindsay Data Analysis and Anode Materials for Lithium Ion Batteries	2004	Postdoctoral Research Fellow University of New South Wales	2004
B Lough Investigations into Thermionic Cooling for Domestic Refrigeration	2004		
BL Luan Investigations on Ti_2Ni Hydrogen Storage Alloy Electrode for Rechargeable Nickel-Metal Hydride Batteries	1997	NRC Fellow National Res. Council of Canada Group Leader Shape Transfer Process Integrated Manufacturing Technologies Institute, NRC, Canada	1997 1999
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
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 Partner-ship Associate University of Leeds and AVX Ltd	2005
D 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 Research Fellow ISEM, University of Wollongong	2002 2004
T Silver Near Bandedge Optical Properties Of MBE Gas And Related Layered Structures	1999	Research Fellow ISEM, University of Wollongong	2000
S Soltanian Development of Superconducting Magnesium Diboride Conductors	2004	Pro-Vice Chancellor Kurdistan University, Iran	2005

PhD Name & Thesis Title	Awarded	Position	When Appointed
K Song Processing And Characterisation Of Superconducting Ag/BiPbSrCaO Composite	1992	Senior Engineer South Korean Co	1993
S Stewart Thermodynamic And Dielectric Properties In Modulated Two-Dimensional Electronic Systems	1998	ARC Postdoc. Fellow Teacher Associate prof	1998 1999 2002
L Sun Amorphous And Nanocrystalline Hydrogen Storage Alloy Materials For Nickel-Metal Hydride Batteries	2000	Research Associate Hydro-Quebec Research Institute, Canada Research Fellow University Sherbrooke, Canada	2000 2002
G Takacs Spectroscopy Of The Effect Of Strains And Magnetic Field On Shallow Acceptor Levels In Germanium	1999	Lab Manager 2nd Year Physics Lab	1999
K. Uprety Magnetic Hysteresis and Relaxation in Bi2212 Single Crystals Doped with Iron and Lead	2002	Research Fellow Argonne National Lab., USA	2002
N Vo Design And Characterisation Of HTS Coils	1997	Research Fellow Los Alamos Nat. Lab, USA Research Staff Intermagnetics General Co., USA	1999 1998
C Wang Cathodic Materials for Nickel-Metal Hydride Batteries	2004	Research Fellow Polymer Institute, University of Wollongong	2004
GX Wang Investigation on electrode materials for lithium-ion batteries	2001	ARC Postdoc. Fellow ISEM, University of Wollongong	2001
J Wang Development of a Novel Plate Making Processing Technique for Manufacturing Valve-Regulated Lead-Acid Batteries	2003	Research Fellow IPRI, University of Wollongong ARC Postdoctoral Fellow ISEM, University of Wollongong	2003 2004
WG 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
XL Wang Spiral Growth, Flux Pinning And Peak Effect In Doped And Pure Bi-2212 HTS Single Crystal	2000	Research Fellow ISEM, University of Wollongong ARC Postdoctoral Fellow ISEM, University of Wollongong ARC QEII Fellow ISEM, University of Wollongong	1999 2002 2005
A Warner A Spectroscopic Study of Acceptors in Germanium	1997	Consultant Computer Industry	1999
JA Xia Characterisation of Melt-Texture of YBCO HTS	1994	Research Fellow Solar Cell Ltd	1995
JM 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
J Yau Ag/Bi-2223 Tape Processing and Mechanical Properties	1994	Assistant Professor City Polytechnical University	2000

PhD Name & Thesis Title	Awarded	Position	When Appointed
M Yavus Powder Processing of Bi-Pb-Sr-Ca-Cu-O Superconducting Materials	1997	Ass. Professor Texas A&M University, Texas USA Ass. Research Professor Tohoku University, Sendai, Japan Ass. Professor University of Waterloo, Canada	2000 1997 2004
B Zeimetz High Temperature Superconducting Tapes & Current Leads	1998	Research Fellow Cambridge Univ., U.K.	1999
R Zeng Processing and characterisation of Bi-2223/Ag superconducting tapes	2000	Research Fellow ISEM, University of Wollongong	2000
S Zhong Investigation on Lead-Calcium-Tin-Aluminium Grid Alloys for Valve-Regulated Lead-Acid batteries	1998	ARC Postdoc. Fellow ISEM, University of Wollongong CEO, Leadcel Dynamic Energy Ltd, P.R. China CEO, Guangzhou Delong Energy Tech Ltd	1997 2002 2003
SH Zhou Processing and Characterisation of MgB_2 Superconductors	2004	STA Fellow Nat. Res. Inst. Of Metals, Japan ARC Postdoc. Fellow ISEM, University of Wollongong	2004 2005

Masters Name & Thesis Title	Awarded	Position	When Appointed
F Chen The Influence of Selenium on Lead-Calcium-Tin-Aluminium	1998	PhD candidate University of Sydney, Australia	1999
M Farhoudi AC Loss in Ag/Bi-2223 Tape in AC Field	2002	PhD candidate ISEM, University of Wollongong	2003
K Ishida Landau Spectra of ZnH and Neutral Zn in Germanium	2004		
JX 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 ARC, PDF ISEM, University of Wollongong	1997 2000
P Lavers The Mobility of Large Anions in Crystals with the Fluorite Structure	2004	PhD Candidate ISEM, University of Wollongong	2004
S Lee Multilayer Thermionic Cooling in GaAs-$Al_xGa_{1-x}As$ Heterostructures	2003		
A Li Fabrication and Characterisation of Novel Substrates and Superconducting Thick Films	2002	PhD Candidate ISEM, University of Wollongong	2002
M Ling	2001		

Masters Name & Thesis Title	Awarded	Position	When Appointed
Mechanism of Outgrowth in Multifilament Bi-2223 tape			
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
JZ Wang Investigations on Anode Materials For Rechargeable Lithium-Ion Batteries	1999	PhD Candidate ISEM, University of Wollongong Research Fellow IPRI, University of Wollongong	2000 2003
G Yang Effect of Element Substitution on Superconductivity	1997	Research Fellow University of Melbourne	2000
J Yao Carbon Based Anode Materials for Lithium-Ion Batteries	2004	PhD Candidate ISEM, University of Wollongong	2004
Q. Yao MgB_2 thin films	2005	PhD Candidate ISEM, University of Wollongong	2005
N Zahir A New Method for Production and Study of Electrical Properties of Carbon Foam	1996	PhD Candidate Queensland University	1997
Z. Zhang The Comparative Research on the Ag-alloy Sheathed Bi-2223 Tapes	2003	Senior Staff China-URC Ltd, Shanghai. PR China	2003
ZW 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

National and International Links

The Institute has established a national and international multi-disciplinary collaborative network. This has led to information exchange, co-supervision of PhD students, joint grant proposals and joint publications with more than 40 research teams around the world. Current collaborative organisations are listed below:

Australia

Australian Nuclear Science & Technology Organisation	Dr. S. Kennedy, Dr. M. James, Dr M. Reinhard
Australian National University	Dr. W. Xu
University of Sydney	Dr. S. Ringer, Dr. R. Keast
Curtin University of Technology	A/Prof. J Low
Macquarie University	A/Prof. E. Goldys
University of Technology, Sydney	Prof. G. Smith
Monash University	Dr. Y.B. Cheng, Krishnamurthy
University of Melbourne	Prof. D. Jamieson
University of New South Wales	Dr. R. Ramer, Prof.M.S.Kazakos, Prof. P. Munroe, Prof. S. Li
University of Western Sydney	Prof. M.M. Wilson
University of Queensland	Prof. G.Q.M. Lu

International

Atomic Institute of Austrian Universities, Vienna, Austria	Prof. H.W. Weber
Brookhaven National Lab	Dr. X.Q. Yang, Dr. Y.M. Zhu
Dalhousie University, Canada	Prof. J. Dahn
Houston University, USA	Prof. R. Weinstein
Institute for Metal Physics, Kiev, Ukraine	Prof. V. Pan
Los Alamos National Lab	Drs A. Serquis and X.Z. Liao
Ludwig Boltzmann Institut für Festkörperphysik, University of Vienna, Austria.	Dr. W. Lang
Max-Planck Institute for Metals Research, Germany	Dr. E.H. Brandt
Max-Planck Institute for Solid State Physics, Germany	Prof. U. Habermeier
Nankai University, PRC	Prof. J. Chen, Prof. Y.H. Tang
Nanjing University	Prof. S.Y. Ding, Prof. W.M. Chen
National Andong University	Prof. J.H. Ahn
North-eastern University, Shenyang, PRC	Prof. X.D. Sun
Lund University, Sweden	Prof. K. A. Chao
Rensselaer Polytechnic Institute	Prof. X. C. Zhang
Ohio State University, Columbus, OH, USA	Dr. E.W. Collings, Dr. M. Sumption
Osaka National Research Institute, Japan	Dr. T. Sakai
University of Auckland	Prof. W. Gao
University of Cincinnati	Prof. D. Shi
University of Wisconsin	Prof. D. Larbalestier, Dr. A. Polyanskii
University of Zagreb, Zagreb, Croatia	Prof. E. Babic, I. Kusevic
Yamagata University, Japan	Dr. S. Kambe, Prof. Ohshima
Kyushu Institute of Technology	Prof. T. Masushita
Institute of Physics, Chinese Academy	Prof H.H. Wen
University of Geneva	Prof. R. Flukiger
Korean Advanced Institute of Science & Technology	Prof. J.Y. Lee
Imperial College	Dr. Cohen,
Philips Research Laboratories and Technical University Eindhoven, The Netherlands	Prof. Dr PHL Notton

Progress Reports for Projects funded by the Australian Research Council

1. Progress Report on ARC Centre of Excellence Research

Develop highly conductive nanocomposite electrodes for Li-battery (*within the ARC Centre of Excellence for Nanostructured Electromaterials, Director: G.G. Wallace)*

Years funded: 2003 2004 2005 2006 2007
Project ID: CE0348245
Chief Investigator: H.K. Liu, G.X. Wang, Z.P. Guo, J.Z. Wang, K. Konstantinov
Partner Investigator: J.Y. Lee, J.H. Ahn

Progress made in 2005

Nanocrystalline transition metal and oxides for lithium storage: The reverse micelle synthesis technique is a universal approach for preparing nanocrystalline metals, oxides and inorganic compounds. Nanosize Ag and SnO_2 nanopowders were successfully synthesised by using the reverse micelle technique. The synthesised Ag powders are very strongly crystalline with a crystal size in the range of 5–20 nm. The SnO_2 powders have a particle size of a few tens of nanometres. The electrochemical performance of nano Ag and SnO_2 powders as anodes in lithium-ion cells was measured. These nanocrystalline anode materials could have significant applications for lithium energy storage and conversion.

Carbon-enriched $Li_{0.98}Mg_{0.02}FePO_4$ compounds were prepared by a novel modified solid-state reaction method. The modified solid-state reaction approach seems ideally suited to offer a degree of control of the material morphology and conductivity. Citric acid added to the precursors works as a particle size growth inhibitor as well as a carbon source. Electrochemical evaluation of the $Li_{0.98}Mg_{0.02}FePO_4$ reveals a lithium insertion plateau around 3.4V vs Li together with a specific capacity of over 160 mAh/g at the C/20 rate. Differential capacity data confirm the two-phase nature of the insertion reaction as well as outstanding ionic reversibility.

PEO based polymer electrolyte: The ionic conductivity of polyethylene oxide (PEO) based solid polymer electrolytes (SPEs) has been improved by the addition of nanosize ceramic powders (TiO_2 and Al_2O_3). The PEO based solid polymer electrolytes were prepared by the solution-casting method. Electrochemical measurement shows that the 10 wt% TiO_2 PEO-$LiClO_4$ polymer electrolyte has the best ionic conductivity (about 10^{-4} S cm^{-1} at 40-60 ^oC). The lithium transference number of the 10 wt% TiO_2 PEO-$LiClO_4$ polymer electrolyte was measured to be 0.47, which is much higher than that of bare PEO polymer electrolyte. AC impedance testing shows that the interface resistance of ceramic-added PEO polymer electrolyte is stable. Linear sweep voltammetry measurement shows that the PEO polymer electrolytes are electrochemically stable in the voltage range of 2.0-5.0 V versus a Li/Li^+ reference electrode.

Silicon/disordered carbon (Si-DC) nanocomposites have been synthesised by high-energy ball milling of Si-sucrose and silicon-polyvinyl alcohol followed by pyrolysis under argon flow. The exact disordered carbon content in the as-prepared Si-DC nanocomposites was determined by thermogravimetric analysis for the first time. Based on the thermogravimetric analysis, X-ray diffraction, Raman, and cyclic voltametric results, we believe that carbon distribution on the Si particles in Si-DC nanocomposite using PVA as the carbon source is more uniform and has higher efficiency than that using sucrose as the carbon source, under the same preparation conditions. The carbon content and the starting polymers significantly affect the electrochemical performance of the Si-DC nanocomposites. The optimised Si-DC nanocomposite anode demonstrated a reversible capacity of 754 mAh/g within 20 cycles.

Nanosize Ag and SnO2 nanopowders were successfully synthesised using the reverse micelle technique. The synthesised Ag powders are very strongly crystalline with a crystal size in the range of 5–20 nm. The SnO2 powders have a particle size of a few tens of nanometres. The electrochemical performance of nano

Ag and SnO2 powders as anodes in lithium-ion cells was measured. These nanocrystalline anode materials could have significant applications for lithium energy storage and conversion.

"Free-standing" single wall carbon nanotube (SWNT) papers have been synthesised by simple filtration method via positive pressure. A conventional SWNT slurry coated electrode was fabricated to compare with the SWNT papers. The results show that the capacity of the "Free-standing" electrode was slightly lower than that of the conventional electrode, but the "Free-standing" electrode was produced without any binder, and metal substrate, so that the weight of electrode was reduced significantly. On the other hand, the procedures for SWNT electrode preparation were simplified, so the cost of the manufacturing could be reduced.

Publications from this project in 2005

Silicon/Disordered Carbon Nanocomposites as Anode Materials for Lithium ion Battery. Guo, Z.P., Millen, E., Wang, J.Z., Chen, J., Liu, H.K. *Journal of Electrochemical Society*, 152 (2005) 11. IF 2.356.

Single wall carbon nanotube paper as anode for lithium-ion battery, Ng, S.H., Wang, J., Guo, Z.P., Chen, J., Wang, G.X., Liu, H.K. *Electrochimica Acta* 51 (2005) 23–28. IF 2.341.

Synthesis of nanocrystalline transition metal and oxides for lithium storage, Wang, G.X., Chen, Y., Yang, L., Yao, J., Needham, S., Liu, H.K., Ahn, J.H. *Journal of Power Sources*, 146 (2005) 487-491. IF 2.513.

Enhancement of ionic conductivity of PEO based polymer electrolyte by the addition of nanosize ceramic powders. Wang, G.X., Yang, L., Wang, J.Z., Liu, H.K., Dou, S.X. *Journal of Nanoscience and Nanotechnology* 5 (2005) 1135 – 1140. IF 2.0.

Fine-particle $Li_{0.98}Mg_{0.02}FePO_4$ synthesised by a Novel Modified Solid-State Reaction. Guo, Z.P., Liu, H., Bewlay, S., Liu H.K., Dou, S.X. *Synthetic Metals* 153 (2005) 113. IF 1.303.

6. S.H. Ng, J. Wang, Z.P. Guo, J. Chen, G.X. Wang, H.K. Liu, Single wall carbon nanotube paper as anode for lithium-ion battery, Electrochimica Acta 51 (2005) 23–28

2. Progress Reports on ARC Large/Discovery Projects

First principles for development of high temperature superconducting wires

Funded:	2002	2003	2004	2005	2006
Project ID:	DP0211240				
Chief Investigators:	S.X. Dou, J. Horvat				
Assoc. Investigators:	H. Weber, E. Collings, J. Habermeier				
Postgrad Students:	S. Keshavarzi, M. Roussel				

Effect of Ag nanodots on $YBa_2Cu_3O_7$ films: $YBa_2Cu_3O_7$ films were deposited by Pulsed Laser Deposition (PLD) on YSZ (100), SrTiO3 (100), and LaAlO3 (100) single crystal substrates. Prior to the film deposition, a discontinuous layer of Ag nano-dots was deposited on the substrates by PLD. The density of Ag nano-dots, was controlled by the numbers of PLD pulses n. J_c increased monotonically with n for films grown on both STO and LAO substrates. However, for films grown on YSZ substrate, J_c increased from $2x10^5$ to $2x10^6$ A/cm^2 as Ag shots increased from 0 to 30, and decreased to $9x10^5$ for n=60. Detailed microstructure investigations indicated that the crystallinity and ab alignment gradually improved as the number of Ag-nano-dots increased.

New biaxially textured substrate for PLD $YBa_2Cu_3O_7$ films: A biaxially textured composite tape of Ni–4.5% Mn/Ni–1.5% Cr was used as a substrate for a $YBa_2Cu_3O_7$ coated conductor, with $CeO_2/YSZ/Y_2O_3$ buffer layer between them. Good biaxial textures have been obtained for buffer layers. The J_c of YBCO films on these metal substrates was 1.5×10^6 A cm^{-2} at 77 K, 0 T. A uniform formation of an Ni–Mn–O layer between NiO and the Ni–4.5% Mn layer was observed after the deposition of $YBa_2Cu_3O_7$. The former layer restricted the further growth of deleterious NiO layer, which was thin and not continuous at high growth pressures and temperatures.

J_c of $Bi_2Sr_2Ca_2Cu_3O_{10}$ single crystals obtained with travelling solvent floating zone technique: Field dependence of J_c close to T_c exhibits a plateau below a characteristic field, associated with thermally activated depinning of individual vortices. The activation energy U_0 is 800K and it scales as $B^{-1/6}$ for B<2T. For B>2T, U_0 is 200K and it scales as $B^{-1/2}$.

Nanoparticle doping of MgB_2: Most of the nanoparticle doping of MgB_2 improves its $J_c(H)$, however some (Cu, Ag) have deleterious effect. Nano-dopants containing carbon (SiC, C-nanotubes) improve both, vortex pinning and upper critical field. Nano-SiC gives the strongest improvement of $J_c(H)$. Doping with Fe and Ti still yields controversial results.

Interaction between superconductor and ferromagnet: Occurrence of the "peak effect" in $J_c(H)$ when MgB_2 wire is sheathed with ferromagnetic material was shown not to be a consequence of self-field. Instead, interactions between the superconductor and magnetic domains, or magnetic dipoles on the surface of the sheath, were singled out as a mechanism for this effect.

S X Dou, et al., IEEE Trans. Applied Supercond., **15** No 2, 3219-3222 (2005).
D Q Shi, et al., Supercond. Sci. Technol., **18**, pp1405-1409, (2005)
J Horvat, et al., Supercond. Sci. Technol. **18**, 682-688, (2005)
J Horvat, et al Appl.Phys.Lett., **87** , 102503(2005).
X L Wang, et al., J. of Appl. Phys., **97**, 1-3 (2005)
D Milliken, et al., *Frontiers in Superconducting Materials*, ed by Narlikar A V, pp554-588, Springer, US, (2005)
A H Li et al.,J. Appl. Phys **97** 10B 107-1-3 (2005) R.
A H Li et al.,, IEEE Trans. Applied Supercond. **15** No. 2 pp. 3046 -3049 (2005)

Analysis, simulation, fabrication and characterisation of reliable, robust and scalable compact cooling elements based on semiconductor nanostructures

Funded: 2003 2004 2005
Project ID: DP0343516
Chief Investigators: C. Zhang, R.A. Lewis
Postgrad students: M. O'Dwyer

Project summary: Modern electronic, microelectronic and optoelectronic devices generally work better when they are cooler. We aim to develop a semiconductor nanostructure cooling element that directly integrates into existing devices. The solid-state cooling element will be reliable, robust, scalable and operate in any orientation. The basis of operation is thermionic emission - electrons are the working fluid. Our project combines (1) analysis and simulation, (2) fabrication of nanostructures and (3) experimental test-benching using optical and electrical methods. The outcome of this research has the potential to revolutionize cooling of modern electronic and photonic systems, from computer motherboards to mobile phones.

(i) We carried out a systemic theoretical and numerical investigation on the effect of barrier shape and device dimensionality on the efficiency and power output of multilayer thermionic devices. The result shows that the total energy filtered system has a clear advantage over the unidirectional filtered system. The result has been published in a comprehensive paper in the Physical Review B.
(ii) We continued to investigate numerically the thermal and electrical measurements on the semiconductor thermionic devices. The asymmetric contact resistance at the top and bottom metal-semiconductor interface were accurately determined.
(iii) We designed the first elementary structure for domestic refrigeration.
(iv) We performed thermal and optical measurements to determine the temporal variation of temperature on various electrodes. We found that the device exhibits a net temperature difference between the case where the device is positively biased and the case where the device is negatively biased. This is the first experimental observation on the cooling effect of a multilayer structure. The measure is now extended to silicon based systems.

Non-linear dynamics in electronic systems and devices under intense terahertz radiation

Funded: 2004 2005 2006
Project ID: DP0452713
Chief Investigators: C. Zhang, R.A. Lewis, X.C. Zhang, R.E. Vickers
Postgraduate student: M. Smith

Project summary: Non-linear interactions allow for a detailed and intricate probing of materials. Sufficiently high-power light directed at a subject can yield spectroscopic data about multiple material parameters, providing a unique diagnostic tool for many applications. We propose to study the non-linear dynamic properties of electronic systems and devices under various external conditions. A thorough understanding of non-linear properties will accelerate development of new optoelectronic devices in the terahertz frequency regime. Examples of these devices are oscillators and sensors. The main activities in 2005 include,

1. Carrying out computation on plasma emission in quantum well under terahertz radiation. Obtained a new acoustic magnetoplasmon mode in terahertz regime

2. Carrying out systematic experimental work on the energy and angular dependence of terahertz power emission from several semiconductor structures. Studied the oscillation properties of holes and p-type emitters and detectors

3. Obtaining a new Hall current in terahertz regime in electronic devices with strong spin-orbit interaction.

4. Studying the vertical transport in semiconductor superlattic

Fabrication, Charge and Spin Ordering, Magnetoresistance, and polaron effects in nano-size and single crystals of novel transition metal perovskite oxide

Funded:	2003	2004	2005
Project ID:	DP0345012		
Chief Investigator:	X.L. Wang, M. Ionescu, Z.X. Cheng		
Partner Investigator:	Dr.M James, Prof. R.S. Liu, Prof. W. Lang		
Postgraduate students:	M. Farhoudi		

The project proceeded as planned. Various new materials scheduled in original proposal have been successfully made and some of them are well characterised. The following are results obtained in the 2005 year period:

1). $HoMn_{1-x}Co_xO_3$ compounds (x=0 up 0.9) were synthesised by solid state reaction. Rietveld refinement from powder X-ray diffraction data indicated that, instead of hexagonal structure with $P6_3cm$ symmetry for $HoMnO_3$, the compounds doped with Co crystallised with $GdFeO_3$-type orthorhombic structure containing distorted $(Co/Mn)O_6$ octahedra. The dc magnetisation was measured in fields up to 5 T over a wide temperature range from 350 K down to 5 K. It was found that the system gradually changed from paramagnetic for x = 0 to ferromagnetic with T_c of 90 K for x=0.5, then to paramagnetic again for x=0.8. The X-ray absorption near-edge spectra (XANES) have been measured to determine the valences of both Co and Mn ions. The results showed that Co and Mn presented mainly as mixed valences of Co^{2+} + $Co^{3+,}$ Mn^{4+} + Mn^{3+}, Co^{3+} +Co^{4+}, and Mn^{4+} depending on the value of x. When the XANES results were combined with Curie Weiss fitting, it was found that both Mn^{4+} and Co^{3+} were present as high spin states for x>0.2, whereas, Co^{4+} appeared in either intermediate or high spin states closely corresponding to the lattice variations along the (010) direction.

2). Far-infrared spectroscopy measurement on polycrystalline perovskite compounds $HoMn_{1-x}Co_xO_3$ (x=0-0.8) shows that the phonon modes significantly changed with increase of cobalt doping level.

3). The structure and phase behaviour of strontium-doped $Ce_{1-x}Sr_xCoO_{3-\delta}$were examined. It was found that the perovskite form is stabilised over a relatively narrow sold solution range (x>0.85). A combination of electron, powder X-ray and neutron diffraction has revealed tetragonal superstructures of the basic perovskite unit: (I4/mmm) $2a_p$ x $2a_p$ x $4a_p$ (x=0.90) and (p4/mmm) a_p x a_p x $2a_p$ (x=0.95). Magnetisation measurement show ferromagnetic behaviour under applied magnetic fields. Low temperatures neutron diffraction of $Ce_{0.10}Sr_{0.90}CoO_{2.80}$ in zero field reveals a magnetic cell of dimension $2a_p$ x $2a_p$ x $4a_p$ with an ordered cobalt moment of 1.7 B.M. at 25 K.

4). High resolution magneto-optical imaging technique was used to study the magnetic field induced transition in ferromagnetic $La_{0.7}Ca_{0.3}MnO_3$. MO images were captured in various magnetic fields over a wide temperature range for both highly dense samples with strong-link grain boundaries and porous sample with weak-link boundaries. Formation and evolution of magnetic domains as a function of fields or temperatures were clearly observed around and far below the Tc. Ferromagnetic areas tend to grow to large sizes and finally join together at the expense of paramagnetic areas as the field increases or temperature decreases for strong-link samples. A sharp magnetoresistance transition is observed when the sample changes from a paramagnetic insulator to a metallic ferromagnetic phase in the vicinity of Tc. In contrast, the porous samples showed magnetoresistance over a wide temperature range and exhibit a remarkable grain boundary related magnetisation process in addition to magnetisation within grains. A close correlation is found between the magnetisation process observed by MOI and magnetoresistance measurements. Our MOI results indicate that the strong-link or weak-link grain boundaries are responsible for magnetoresistance occurring either only in the vicinity of the ferromagnetic transition or over a very wide temperature range.

5). A $BiFeO_3$ and $Bi_4Ti_3O_{12}$ double layered thin films on platinized silicon was fabricated by pulse laser deposition method. Large enhancement of ferromagnetic moment and polarisation was observed. In the

double layer thin films, $Bi_4Ti_3O_{12}$ works a barrier layer, which stops the leakage current, thus the polarisation was enhanced. While the enhancement of magnetic moment is from the epitaxial growth of $BiFeO_3$ layer.

Control of nano-structure for enhancing the performance of magnesium diboride superconductor by chemical doping

Funded:	2004	2005	2006
Project ID:	DP0449629		
Chief Investigators:	S.X. Dou, M.J. Qin		
Partner Investigators:	D.C. Larbalestier, R.L. Flükiger, L.F. Cohen		
Postgrad. Students	W.K. Yeoh, O. Sherbakova, Y. Zhang		

Enhancement of H_{c2} and H_{irr} of MgB_2 wires by SiC doping: We have carried out systematic investigation on the enhancement of H_{c2} and H_{irr} of MgB_2 wires with various kinds of SiC dopants under various heating conditions. Higher values of H_{irr} and H_{c2} were seen for wires heated at higher temperatures and, in some cases, longer times. Wires with finer SiC powders also had larger H_{irr} and H_{c2} values. The highest critical-field values were seen for a wire with 15 nm SiC additions which after 725 °C for 30 min had a H_{irr} of 29 T and a H_{c2} greater than 33 T.

Improvement of the critical current density by nano-doping: We continue to study the effect of sintering temperature on the phase formation, J_c, H_{c2}, H_{irr} and nanostructure of nano-SiC doped MgB_2 superconductors. It was found that low temperature sintering resulted in a higher concentration of impurity precipitates, larger resistivity, higher J_c and lower T_c values. While high temperature sintering resulted in smaller resistivity, lower Jc and higher Tc value. It is proposed that the huge local strain produced by nano-precipitates and grain boundary structures are the dominant mechanism responsible for higher H_{c2} near T_c.

Effect of Iron doping: We have demonstrated that nanoscale Fe particle doping depressed both T_c and $J_c(H)$ in both bulk and thin film samples. Because of their high reactivity, in the *in situ* process the nanoscale Fe particles reacted with B to form FeB andFe_2 B, which were homogeneously distributed within the matrix of bulk and thin filmMgB_2. Fe substitution for Mg is estimated to be at the level of 1% of Mg which is proposed to be responsible for the depression in T_c. The strong depression in $J_c(H)$ performance caused by nano-Fe particle doping is attributable to both the weak link effect of Fe and FeB particles at grain boundaries and the pair-breaking effect of Fe substitution for Mg in the lattice.

MgB2 thin film fabrication: Highly smooth and *c*-axis oriented superconducting MgB_2 on Al_2O_3–C substrates thin films were prepared by pulsed laser deposition (PLD). An *in situ* annealing was carried out at 650 ^oC for 1 min in a 760 Torr Ar atmosphere. An x-ray θ–2θ scan shows fairly good crystallisation with crystallite size less than 50 nm. The root mean square roughness of our off-axis film is 4 nm in a $5 \times 5\ \mu m^2$ area. The T_c onset value of the best off-axis film reaches 33.1 K with a narrow transition width of 0.9 K. The films showed no anisotropy in H_{c2}–T curves when parallel and perpendicular fields were applied. The slope of the H_{c2}–T curves in the low field regime is 1 T/K, which is among the highest reported value.

Study flux jumps and flux pinning in MgB2 thin films: We have carried out studies on two types of MgB2 thin films produced by PLD with different *in situ* and *ex situ* sintering routes. Using the magneto-optical (MO) imaging technique, the magnetic flux penetration behaviour in the films has been investigated. In the case of the *in situ* film, the MO observations reveal conventional flux jumps below the corresponding threshold temperature, whereas in the case of the *ex situ* film the flux jumps appear to take the form of unusual, structurally driven 'blob'-like patterns. The underlying structural features of the films have been investigated by scanning electron and atomic force microscopy. A mechanism for the structurally driven, spatially reproducible flux jumps is proposed.

Five articles have been published in international journals: 1) Superconductor Science and Technology, 18 (2005) 710**,** 2) Applied Physics Letters, 86**,** 092507 (2005), 3) Superconductor Science and Technology, 18 (2005) 658, 4) Superconductor Science and Technology, 18 (2005) 1391, 5) Superconductor Science and Technology, 18 (2005) 395.

Hydrogen storage materials for energy conversion applications

Funded:	2004	2005	2006
Project ID:	DP0449660		
Chief Investigators:	H.K. Liu, Z.P. Guo (APD)		
Partner Investigators:	J. Lee, A. Zuettel, P.H. Notten		

Progress made in 2005

Thermal stability and hydrogen storage property of $Mg_{1.9}Cu_{0.1}Ni_x$ (x = 1.8, 1.9, 2.0 and 2.1) alloys were investigated. It was found that nickel content in the alloys predominantly affects the crystallisation, hydrogenation-desorption temperatures. With the increase of nickel content, the crystallisation temperature increases, the hydride content becomes less and the desorption temperature decreases. The calculated values of formation enthalpy of nickel monovacancy are 61.5 kJ/mol, 62.6 kJ/mol, 63.8 kJ/mol and 64.9 kJ/mol corresponding to nickel content 1.8, 1.9, 2.0 and 2.1, which demonstrate that the thermal stability of the as-prepared alloys, the hydrogenation ability and desorption kinetics are closely related with the nickel content.

MgH_2-carbon composites for hydrogen storage have been synthesised by Controlled Reactive Mechanical Ball Milling (CRMBM) of carbon allotropes and magnesium in hydrogen. The structure of carbon black, graphite and carbon nanotube before and after ball milling has been investigated through XRD and Raman spectrometer. From the XRD pattern, it is clear that all magnesium powder has reacted with hydrogen and formed a hydride. The integrated intensity ratio of I_D/I_G in the Raman Spectra of all the carbon allotropes increases after ball milling with graphite showing the greatest change value, implying the most severe disruption of graphitic structure in the carbon allotropes. SEM images and EDS mapping of the powders show that the three kinds of carbon are uniformly distributed throughout the powders and more than 20 wt % of the carbon is on the surface of the magnesium hydride. Although no big difference exists in the hydrogen storage capacity in the as-received (6.4 %) and rehydrogenated (6.2%) composites, the rehydrogenated composite containing graphite shows a distinguished decrease in the desorption temperature, which is highly worthy for further investigation in Mg based hydrogen storage system.

Effects of iron oxide (Fe_2O_3, Fe_3O_4) on hydrogen storage property of Mg-based composites were also investigated. Fe_2O_3 and Fe_3O_4, where Fe has different valence, were ball milled with magnesium in hydrogen through a special low-shearing mode Uni-Ball-Mill 5. During hydrogen desorption, these two iron oxides were reduced by magnesium, which was never reported before. This was attributed to the special ball milling equipment, which provides pure low-energy shearing mode during the whole milling procedure. There is not much difference in the decomposition temperature of as-prepared and rehydrogenated composites. However, there is a capacity degradation for the rehydrogenated composites (4 % for MgH_2 + Fe_2O_3, and 4.4 % for MgH_2 + Fe_3O_4), compared with the as-prepared ones (6 % for MgH_2 + Fe_2O_3, and 5 % for MgH_2 + Fe_3O_4), which results from the reduction reaction.

Another part we studied is hydrogen storage behaviour in spherical clusters of metal-oxide nanowires. Spherical clusters of transition-metal oxide nanowires were prepared by using a simple, rapid and easily scaled up method, i.e. chemical precipitation followed by thermal decomposition. The microstructure characteristics of spherical clusters of nanowires were examined by scanning electron microscopy (SEM). It was found that the nanowires were not only displayed on the surface of the spherical particles, but also existed inside the particles. Hydrogen adsorption/desorption experiments were carried out at room temperature. A hydrogen storage capacity of 0.71% was achieved under a pressure of 3.05 MPa for the spherical clusters of doped NiO nanowires with a surface area of 113.39 m^2/g, and about 66.8% of the stored hydrogen could be released under ambient pressure.

Publications from this project in 2005

1. Z.P. Guo, S.H. Ng, J.Z. Wang, Z.G. Huang, H.K. Liu, C.O. Too and G.G. Wallace, "Electrochemical Hydrogen Storage in Single-Walled Carbon Nanotube Paper", J. Nanoscience and Nanotechnology (in press, accepted in October 2005).

2. Z.P. Guo, Z.G. Huang, K. Konstantinov, H.K. Liu, S.X. Dou, "Electrochemical Hydrogen Storage Properties of Nonstoichiometric Amorphous MgNi1+x-carbon Composites (x = 0.05-0.3)", International Journal of Hydrogen Energy (in press, accept in Dec. 2005).

3. Z.G. Hang , Z.P. Guo , D. Wexler , A. Calka, C. Lukey , H.K. Liu, "Effects of iron oxide (Fe_2O_3, Fe_3O_4) on hydrogen storage property of Mg-based composites", J. Alloys and Compounds (in press, Accepted in Dec. 2005).

4. Z.G. Huang, Z.P. Guo, H.K. Liu, S.X. Dou, "Effect of Ni Content On the Structural and Electrochemical Properties of the $Mg_{1.9}Cu_{0.1}Ni_{\chi}$ hydride alloys", J. New Materials for Electrochemical Systems (in press, Accepted in May 2005).

5. Z.P. Guo, Z.G. Huang, Z.W. Zhao, X. Menard, H.K. Liu, "Enhanced Electrochemical Properties of Nonstoichiometric Amorphous $Mg_2Ni_{1.3}$ Electrodes", J. Applied Electrochemistry (In press, accepted in April 2005).

Development of high-temperature superconducting coated conductors by pulsed-laser deposition technique for future long-length applications

Funded:	2004	2005	2006
Project ID:	DP0451267		
Chief Investigators:	A.V. Pan (APD), M. Ionescu		

The aim of the project is to develop a novel technology for manufacturing flexible coated conductors with the help of a pulsed laser deposition technique, in order to enhance the current-carrying ability of high-temperature superconducting coatings (including multi-layered coatings) for future long-length high power applications. To achieve desirable electromagnetic properties governed by the nano-structures of the coatings, a well-balanced combination of world-class "global" and "local" electromagnetic property measurements with advanced structural characterisations is suggested. It is expected that a controlled network of nano-scale pinning centres will allow the development of high performance coated conductors.

The major achievements in 2005 were:

Two different models are developed for vortex pining/supercurrent limitation and for low field behaviour of the characteristic field (B*), separating the Ba-independent critical current density (J_c) plateau (single vortex pinning regime) and the region with $J_c(B_a)$ (collective pinning) in YBCO films. The models proposed show an excellent agreement with obtained experimental data. One model shows that rows of growth-induced out-of-plane edge dislocations forming low angle boundaries (LABs) play a key role in achievement of the highest critical current density J_c. It also takes into account the transparency of LABs for supercurrent as well as the pinning of vortex lattice on a network of LABs. The other model attributes the temperature behaviour of B^* to thermally activated processes for HTS superconductors in general and for YBCO films in particular. This is in contrast to LTS and MgB2 superconductors. These two models are accepted into two different Phys. Rev. B papers).

High quality YBa2Cu3O7 (YBCO) films and multilayers of $ReBa_2Cu_3O_7$ superconductors, where Re is rare earth elements (Y and Nd), have been prepared by pulsed laser deposition, which parameters were tuned and optimised. Pinning characteristics of the structures obtained have been analysed and attributed to growth conditions and corresponding structural peculiarities. Relatively thick (~ 1 μm) multilayers exhibit better performance than mono-layer YBCO films having arbitrary thickness. Differences in the films and multilayers are discussed in terms of their structure homogeneity and defects induced by the growth of the layers. Different aspects of this work were presented at two international conferences, one paper is accepted in Inst. Phys. Conf. Ser, and one is accepted to Appl. Phys. Lett.

Synthesis of nanowires and applications as nanosensors for chemical and biological detection

Funded:	2005	2006	2007
Project ID:	DP0559891		

Chief Investigators: G.X. Wang, K. Konstantinov
Partner investigator: J.H. Ahn, X.Q. Yang and Z.L. Xiao

In the year 2005, we designed, fabricated and installed two experimental facilities for synthesis of semiconductor nanowires. One is chemical vapour deposition system (CVD) and another is pulsed laser deposition system. These two systems are essential infrastructure for future research.

One dimensional CdSe nanostructures, including nanowires, nanotubes, nanorods, nanobelts, and even nanostructures resembling saws and tree branches, have been successfully synthesised by sublimation of CdSe powders under various experimental conditions. These 1D CdSe nanostructures were characterised by SEM, TEM observation, and Raman spectroscopy. EDS analysis confirmed the chemical stoichiometry of the CdSe nanostructures. We have identified numerous factors influencing the growth, morphologies, and dimensionality of CdSe 1D nanostructures, illustrating that the geometrical characteristics of CdSe nanostructures can be controlled by the synthetic parameters. Raman spectra measurement shows an upward shift of the 2LO phonon peak of CdSe nanowires. One-dimensional CdSe nanostructures could provide functional building blocks for nanoscale electronic and optoelectronic devices. It is necessary to further map up the controllable synthesis of CdSe 1D nanostructures.

One-dimensional Si nanostructures, including Si nanowires, nanobelts and nanosheets, were synthesised by sublimation of nanosize silicon powders. The diameter, length, and morphology of the Si 1D nanostructures were found to vary with the synthetic conditions. TEM observation identified that the growth of the Si nanowires follows a vapour – liquid – solid (VLS) process. This provides a practical technique for the synthesis of large quantities of Si nanowires. The small diameter of the nanowires provides a short diffusion length for electrochemical reactions. The main obstacle to the commercialisation of Si and other alloy anode materials is the significant volume change resulting from the electrochemical reaction when forming alloys. This will cause cracks and degradation of the electrode, inducing poor cycle life. However, if the active electrode consists of one-dimensional nanowires, the above effect will be dramatically alleviated. This is because the volume expansion will be homogeneous along the radial direction. If there is sufficient space between nanowires, such expansions can be effectively self-absorbed. Therefore, mechanical stress and the loss of contact, which induces capacity fading will be minimised. We proposed two models (parallel model and random model) describing the electrochemical reaction. The situation of the Si nanowire thin-film electrodes that we deposited on stainless steel substrates is similar to the random model. Mechanical stress still exists at the points where the nanowires cross, accompanied by volume changes. The parallel model represents an ideal case for Si nanowire electrode. If we can align Si nanowires in an appropriate density and pattern, the extent of volume expansion of the Si nanowires can be precisely controlled to fill the gaps between individual Si nanowires. In that case, there will be zero mechanical stress on the electrode when the electrochemical reaction takes place. The integrity of the electrode can be preserved under repeated cycling. The assembly of random nanowires into aligned patterns has been realised by using various techniques, including fluidic-directed assembly, electric-field directed assembly, and the Langmuir-Blodgett technique. We are currently working on the synthesis of homogeneously straight Si nanowires and assembling them into designed parallel patterns.

G.X. Wang, M.S. Park, D. Wexler, J. Chen and H.K. Liu "Synthesis and characterisation of one dimensional CdSe nanostructures", Applied Physics Letters (in press).

Exploration for new materials for spintronics

Funded:	2005	2006	2007	2008	2009
Project ID:	DP0558753				
Chief Investigators:	X. L. Wang				

A series of novel transparent oxide diluted magnetic semiconductors have been discovered and systematically studied by Rietfield refinement, transport, and magnetic measurements, and synchrotron radiation.

1.1). Room-temperature diluted ferromagnetic (In0.9Fe0.1-xMnx)2O3 oxide was successfully synthesised and characterised. All of the samples with intermediate x values are ferromagnetic at room temperature. The highest saturation magnetisation moment at 300 K per total amount of magnetic ion is reached in the (In0.9Fe0.04Mn0.06)2O3 sample. The lattice constant increases linearly with increasing Mn content.

1.2). (In0.9Mn0.1)2O3 compound was found to be ferromagnetic at Tc = 46 K. While (In0.9Fe0.1)2O3 compound is paramagnetic.

1.3). Room-temperature ferromagnetic properties were discovered in both Fe and Mn co-doped transparent oxide semiconductor In2O3-SnO2. Mn and Fe co-doped ITO transparent semiconductors, In1.8-xMn0.12Fe0.08SnxO3 (x=0, 0.02, 0.04, 0.06) were synthesised by equilibrium solid state reaction process and characterised using Rietveld refinement, transport and magnetic measurements. All the compounds are ferromagnetic at room temperature with saturation moments of 0.16-0.8 μB/(Mn+Fe). Electrical conductivity was found to increase with increase in Sn contents. Results of structure refinements and assessments of spin states indicated that both Mn and Fe ions are situated at octahedral indium sites and present as Mn3+ and Fe3+ with intermediate and low spin states, respectively.

1.4). The magnetic properties and the Co K-edge x-ray absorption spectroscopy (XAS) study of polycrystalline bulk Zn1-xCoxO (x = 0.10, 0.15, 0.17) samples prepared using conventional equilibrium solid state reaction. All samples showed a paramagnetic behaviour and no ferromagnetism were observed. XAS results showed that for all samples the valence of Co is 2+. Spin state assessment derived from Currie-Weiss fitting indicated a possible spin state transition from Co2+ high spin (HS) to Co2+ intermediate spin (IS) for samples with x = 0.10 and 0.15.

1.5). Polycrystalline samples of In and Co co-doped ZnO (Zn1-xInxCo0.075O) oxide were prepared by "rapid oxalate decomposition" technique. Phase purity and structure refinement done by means of Rietveld analysis technique showed that both Co and In substitute properly into Zn positions. Indium doping increased the bulk conductivity of the samples at room temperature indicating an increase of charge carrier concentration. All samples showed paramagnetic behaviour following Curie-Weiss law at close to room temperatures, with short range antiferromagnetic interaction. Effective magnetic moment μeff calculations showed strong orbital contribution to the value of μeff increasing with increase of In content (x). Despite the fact that the high itinerant carrier concentration was achieved, no ferromagnetism was observed, suggesting that other mechanisms rather than carrier induced ferromagnetism might be considered as an origin of ferromagnetism in diluted magnetic semiconductors.

2. A series of two dimensional novel cobalt magnetic oxides have been successfully synthesised and systematically studied using XRD, Rietveld refinement, transport and magnetic measurement.

Development of new technology for coated conductors able to carry "over-critical" current densities

Funded:	2005	2006	2007
Project ID:	DP0557544		
Chief Investigators:	A.V. Pan, S. Zhou, Yu. Genenko, and T. H. Johansen		

The development of a new magnetically induced current redistribution (MICR) technology for long superconducting wires/coated conductors based on the "long-range" magnetic interaction between the magnetic environment and the superconductor is the aim of the project. This new approach is expected to drastically enhance the current-carrying properties of the superconductors for different power applications. The significance of the project is not only in the possible application of this new MICR method, but also in the fundamental understanding of magnetic interactions of this kind.

The general aim of this project is the development of coated conductors capable of carrying extraordinary, dissipation-free, "over-critical" current densities. This would include:
(1) Establishment and testing a physical model of coated conductors carrying overcritical currents using theoretical and experimental approaches on YBCO films and MgB_2 wires.

(2) If the experimental model is successful, the development of a novel technology for implementation of this innovation in practice for YBCO-coated conductors is planned.

The following progress has been made during about 5 months since the commencement of the project:

The magnetic behaviour of iron sheathed MgB2 wires was investigated. Global magnetisation measurements have shown unusual critical current density variations compare to a superconductor with no magnetic environment. Local quantitative studies by MO imaging have been linked to these global magnetisation measurements in order to better understand the observed results. The supercurrent distribution quantified from MOI was shown to be affected by the soft magnetic sheath interacting with the superconducting core. The results were presented at a conference and will be published by Inst. Phys. Conf. Ser. in 2006.

Further, our attempts on designing an appropriate magnetic environment showed a strong influence of magnets and YBCO films, however, no current enhancement has been seen yet due to imperfect design of the experiments. In addition, we have carried out numerous experiments on systematic variation of pinning level in MgB_2 wire samples by different dopants. The results have been submitted for a publication.

3. Progress Report on SPIRT/Linkage Programs

Lithium/sulfur rechargeable battery for power applications

Funded:	2004	2005	2006
Project ID:	LP0453698		
Chief Investigators:	H.K. Liu, J.Z. Wang (APD), G. Wang		
Industry Partner:	Guangzho Delong Energy Technology Pty Ltd		

Progress made in 2005

(1) Sulphur-Polypyrrole Composite Positive Electrode Materials
Sulphur-polypyrrole (S-PPy) composites were prepared by an optimised chemical polymerisation method. For quantifying the amount of polypyrrole in the S-PPy composite materials, TGA analysis was carried out. The results indicated that the S-PPy composite contained about 40 wt.% PPy. SEM images of the bare sulphur powder and S-PPy composite are measured. The particle size of the sulphur ranges from 1-10 microns. After introducing the PPy, the smaller and more porous PPy particles uniformly coated the surface of the S particles. At high magnification, we see that the PPy particles are in the range of 200-500 nm. The PPy matrix reduces the particle-to-particle contact resistance, thus significantly enhancing the electrical conductivity of the composite. The results presented that the discharge capacities of sulphur and S-PPy composite was improved and the cyclic durability of the S-PPy composite electrode was also improved. The improvement in the capacity and cyclic durability of the cell with S-PPy composite electrode may be due to the following factors: (i) Conductive PPy coating on the surface of the sulphur can improve the conductivity of S-PPy electrode. At the same time, PPy can also act as a binder, increasing the contact between particles. (ii) The capacity of the S-PPy composite electrode is higher than that of the pure S electrode. This may be due to the presence of polypyrrole, which acts not only as a conducting additive but also as an active material contributing to capacity of the electrode during cycling, as confirmed in the CV measurements. (iii) PPy nanoparticles coated onto the surface of S powder may absorb polysulfide due to their porous surface morphology and reduce the dissolution of the polysulfide into the electrolyte. Consequently, the sulphur utilization and cyclic durability were improved.

Therefore, the conductive polypyrrole serves multiple purposes in the composite when it is used in a lithium cell: as a conducting additive, an active material, and an adsorbing agent.

(2) Microemulsion- Mediated Synthesis of Nanosize MoS_3 Cathode Materials
In this work, nanosized amorphous molybdenum trisulphide has been synthesised using a microemulsion-based method. Nanosize particles MoS_3 were synthesised in the polyoxyethylene nonylphenyl ether/cyclohexane/water microemulsion system by acidifying ammonium tetrathiomolybdate, $(NH_4)_2MoS_4$ solubilized in the water cores of the inverse micelles. For comparison, amorphous molybdenum sulphide was synthesised and tested by using conventional thermally decomposing ammonium tetrathiomolybdate. The possibility of using MoS_3 nanopowders as cathode materials for lithium rechargeable batteries has been examined.

SEM micrographs of the two powers are shown that the MoS_3 powders synthesised using microemulsion-based method are agglomerates with a uniform nanosize and consist of cotton-like structures, and the powder prepared from thermal decomposition method has a totally different microstructure. The discharge capacity was improved for the electrode using microemulsion-based method in the lithium cell. The initial capacity of MoS_3 electrode made using microemulsion-based method was about 25% higher than that of the conventional of thermal decomposition method.

(3) Coating protective layer on lithium anode with an organic solvent
A dioxolane liquid was used in the electrolyte as a solvent. The protective layer would be coated on the surface of the lithium anode to prevent the lithium from reacting with a wide range of materials, which can contaminate battery cells, particularly moisture and other impurities that might react with the lithium to the detriment of its function as a negative electrode in a battery cell. But the results show that the performance of the Lithium/sulphur was not improved significantly.

Three papers have been accepted for publishing in peer-reviewed Journals

J. Wang, G.X Wang, L. Yang, S.H. Ng and H.K. Liu, "An Investigation of Electrochemical Behaviour of Nanosize Zinc Sulphide Electrode in Lithium-ion Cells" *Journal of Solid State Electrochemistry* (on line available in April 2004)

J. Wang, S.H. Ng, G.X. Wang, J. Chen, L. Zhao, Y. Chen and H.K. Liu, Synthesis and Characterisation of Nanosize Cobalt Sulphide for Rechargeable Lithium Batteries", *Journal of Power Sources,* (Accepted in Oct. 2005).

J. Wang, J. Chen, K. Konstantinov, L. Zhao, S.H. Ng, G.X. Wang, Z.P. Guo, H.K Liu, "Sulphur-Polypyrrole Composite Positive Electrode Materials for Rechargeable Lithium Batteries", *Electrochimica Acta,* (accepted in Jan. 2006).

Large-scale rechargeable lithium battery for power storage and electric vehicle applications

Funded: 2004 2005 2006
Project ID: LP0453766
Chief Investigator: G.X. Wang, K. Konstantinov and H.K. Liu
Partner investigator: J.H. Ahn and B. Ammundsen

We have investigated a number new cathode materials, anode materials and polymer electrolyte for lithium-ion batteries. Lithium iron phosphate and Mg doped lithium iron phosphates were synthesised via the sol-gel route. It was found that the sintering temperature has significant influences on the crystal size and impurities of $LiFePO_4$ and $Li_{0.95}Mg_{0.05}FePO_4$ compounds. Iron phosphides, which are electronic conductors, were formed when sintering at 850 °C. Magnetic susceptibility measurements on the samples show antiferromagnetic behaviour with $T_N = 50 \pm 2$ K for $LiFePO_4$ and $Li_{0.95}Mg_{0.05}PO_4$ sintered at temperatures below 850 °C. The $LiFePO_4$ and $Li_{0.95}Mg_{0.05}$FePO4 cathodes show a stable electrochemical capacity in the range of 150 – 160 mAh/g on cycling. $LiMn_xFe_{1-x}PO_4$ (x = 0, 0.1, 0.3, 0.5, 0.7, 0.9, 1) compounds were synthesised by a sol-gel preparation route. X-ray diffraction and Rietveld structure refinement revealed that the lattice parameters (a, b and c) of orthorhombic $LiMn_xFe_{1-x}PO_4$ increase with increasing Mn content. Magnetic susceptibility measurements show antiferromagnetic behaviour for $LiMn_xFe_{1-x}PO_4$ samples. The electrochemical performance of $LiMn_xFe_{1-x}PO_4$ degrades with increasing Mn content. Therefore, undoped $LiFePO_4$ is the best choice as a cathode material for Li-ion batteries.

The ionic conductivity of polyethylene oxide (PEO) based solid polymer electrolytes (SPEs) has been improved by the addition of nanosize ceramic powders (TiO_2 and Al_2O_3). The PEO based solid polymer electrolytes were prepared by the solution casting method. Electrochemical measurement shows that the 10 wt% TiO_2 PEO-$LiClO_4$ polymer electrolyte has the best ionic conductivity (about 10^{-4} Scm^{-1} at 40 °C – 60 °C). The lithium transference number of the 10 wt% TiO_2 PEO-$LiClO_4$ polymer electrolyte was measured to be 0.47, which is much higher than that of bare PEO polymer electrolyte. Cyclic voltammetry measurement shows that the PEO polymer electrolytes are electrochemically stable in the voltage range of 2.0 – 5.0 V versus a Li/Li^+ reference electrode.

Nickel oxide (NiO) nanotubes have been produced for the first time via a template processing method. Individual nanotubes measured 60 μm in length with a 200 nm outer diameter and a wall thickness of 20-30 nm. The NiO nanotube powder was used in Li-ion cells for assessment of the lithium storage ability. Preliminary testing indicates that the cells demonstrate controlled and sustainable lithium diffusion after the formation of an SEI. Reversible capacities in the 300 mAh g^{-1} range were typical. High purity nanometre-sized SnSb and Sn/SnSb anode materials have been synthesised by using chemical co-precipitation from aqueous solution. The addition of increasing quantities of carbon black improved the capacity of SnSb and Sn/SnSb electrodes by allowing a better utilisation of active particles and superior electrical conduction. Co_3O_4 – C composite powder has been synthesised via spray pyrolysis of cobalt nitrate-sugar solution at 600 °C and assessed for application in Li-ion batteries. Microstructural characterisation by SEM, TEM and EDXS confirm an even distribution of C throughout particles, as well as the presence of a C based surface

sheath surrounding Co_3O_4 – C particle agglomerates. Charge-discharge cycling of half cells indicates a stable reversible discharge capacity above 800 mAh g^{-1}.

G.X. Wang, L. Yang, J.Z. Wang, H.K. Liu and S.X. Dou, "Enhancement of ionic conductivity of PEO based polymer electrolyte by the addition of nanosize ceramic powders" Journal of Nanoscience and Nanotechnology **5** (2005) 1135 - 1140.

S.A. Needham, G.X. Wang and H.K. Liu, "Synthesis of NiO nanotubes for use as negative electrodes in lithium-ion batteries" Journal of Nanoscience and Nanotechnology **6** (2006) 77-81.

S.A. Needham, G.X. Wang and H.K. Liu, "Synthesis and Electrochemical Performance of SnSb and Sn/SnSb as Anode Materials for Lithium Storage" J. Alloys and Compound **400** (2005) 234

J. Yao, K. Konstantinov, G.X. Wang, and H.K. Liu, "Electrochemical and magnetic characterisation of $LiFePO_4$ and $Li_{0.95}Mg_{0.05}FePO_5$ cathode materials", Journal of Solid State Electrochemistry (available online Dec. 13, 2005).

J. Yao, S. Bewlay, V.A. Drozd, R.S. Liu, X.L. Wang, H.K. Liu and G.X. Wang, "Characterisation of olivine-type $LiMn_xFe_{1-x}PO_4$ cathode materials" Journal of Alloys and compounds (accepted on Jan. 16, 2006, in press).

Development of Magnesium Diboride Superconductor wires with high upper critical field for MRI applications

Funded: 2005 2006 2007
Project ID: LP0560280
Chief Investigator: S.X. Dou, M.J. Qin, A. V. Pan, X.L. Wang, E.W. Collings
Industry partners: Hyper Tech Research Inc. OH USA, Alphatech International Ltd. Sydney

(1) The doping effect of multi wall carbon nanotube on MgB_2/Fe superconductor wire: We evaluated the doping effect of carbon nanotube (CNT) with different aspect ratios on MgB_2/Fe wire. Relationships between microstructure, J_c, T_c, H_{c2}, and H_{irr} for both short and long CNT doped wires were systematically studied. We observed that all samples sintered at different temperature from 650 to 900°C seem to be a well-developed MgB_2 with small amount of MgO. However, the FWHM of the (100) peak of short CNT wire increased with sintering temperature. This indicates that lattice defects and depressed crystallinity have occurred due to short CNT doping. Since the short CNT has a smaller aspect ratio, resembling that of a nano-carbon source, when compared with the long one, short CNT could be substituting for B and included within the MgB_2 grains. Specifically, short CNT doped samples sintered at high temperatures exhibited excellent J_c, ~10^4 A/cm^2 up to 8 T at 5 K. The J_c of the sample sintered at the highest temperature showed a crossover with that of the low temperature one around 5 T. This result indicates that flux pinning for samples produced at a high sintering temperature was enhanced by short CNT doping. In addition, the short CNT doped sample presented a larger dH_{c2}/dT, compared with the pure and the long one. The short CNTs are thus believed to increase the intra-band scattering, shorten the mean free path and coherence length. The short CNT is a promising carbon source for MgB_2 superconductor with excellent J_c.

(2) Effect of B powder purity on superconducting properties of MgB_2: We have shown that the purity of starting B powders are important in determining the $J_c(B)$ performance of MgB_2 sample, the purer the starting B powders, the better the $J_c(B)$ performance. We have purified 92% and 96% B powders using a simple chemical leaching process, resulting in enhanced $J_c(B)$ performance. However, compared to the pure 99% powder, the purified powders still show more oxide impurities, lower surface reactivity, less uniform grain distributions, and larger grain size, further works are needed in order to use the 92% or 96% powders to make MgB_2 wires for industrial applications.

(3) Effect of nano-C doping: The effect of MgB_2 doping with nano C on T_c, lattice parameters, J_c, and flux pinning was studied for bulk, wire and tape under a wide range of processing conditions, Enhanced of J_c was observed at the higher sintering temperature, which is caused by the C substitution for B with increasing

sintering temperature. Under the optimum condition, magnetic J_c was enhanced by two orders at 5 K for the field of 8 T, and factor of 33 at 20 K for the field of 5 T were achieved in the bulk sample while enhanced by factor of 5.7 was observed in the transport I_c in the 12 T at 4.2 K for wire sample. Highly dispersed nano-particles under TEM are believed to contribute the flux pinning despite the introduction of pinning centres by C substitution.

(1) IEEE Trans, Appl. Supercond., **15**, pp 3284, 2005,
(2) Supercond. Sci. Technol., **19**, pp L5, 2006,
(3) Appl. Phys. Lett., **87**, pp 182504, 2005.
1 article will be published in Advanced Materials.

Enhancing the Understanding and Performance of Passivating TiO_2 Coatings for Photovoltaic Devices

Funded:	2004	2005	2006	2007
Project ID:	LP0455328			
Chief Investigator:	Richards, McIntosh, Provancha, Swanson, Ionescu			
Industry partners:	Keith McIntosh Consulting, Sierra Therm Production Furnaces, Inc. Sun Power Corporation			

After the initial slow start to this grant, we are now getting up to speed. Dr. Keith McIntosh is in the process of being added as the second CI to the grant, since he is now employed at ANU. In addition, we have recently attracted two further PhD students who will also work on aspects of surface passivation and dielectric thin films that are related to the project. Naturally, this will greatly enhance the productivity of our team. The following research tasks, planned for the first year of the project (10/3/05 – 9/3/06), and their current status is:

1. SiO2 films have been deposited and the majority of time has been spent understanding these layers for two reasons. Firstly, SiO2 are the best characterised films in the literature and, secondly, they will form part of future multi-layer stacks with TiO2/SiO2.
2. Deposit and characterise of TiO2 (e-beam, sputtered, pulse laser deposition). This has not been possible as this equipment was at UOW but is not at ANU. For the most part, most necessary items of equipment were available, expect for Raman and x-ray photoelectron spectroscopes (XPS). This will make surface analysis somewhat more difficult or expensive.
3. Specify and order APCVD TiO2 system – completed and delivery occurred on 21/2/06.
5. Deposit and characterise of TiO2 (APCVD), can now begin in March after commissioning of the APCVD tool.
6. Develop methods for characterising films on textured Si. The literature research for this research goal has begun, which suggest that spectroscopic techniques such as Raman and FT-IR spectroscopy can yield useful information about the thin film: silicon wafer interface.

In addition, several major items of equipment have been purchased that are relevant to this project, including a capacitance-voltage system and a weathering chamber (light, heat and humidity).

Our research plans and objectives for the coming year are to:

1. Continue deposit and characterise SiO2 thin films and their interface quality with silicon
2. Deposit and characterise of APCVD TiO2 thin films
3. Continue developing methods for characterising films on textured Si
4. Investigate effects of Cs-doping at TiO2:Si interface
5. Investigate effects of hydrogen in TiO2 during deposition
6. Investigate effects of hydrogen in TiO2 post-deposition
7. Investigate environmental testing of surface passivation schemes

B.S. Richards, N.T.P. Huong, A. Crosky (2005), *Highly Porous Nanocluster TiO2 Films Deposited using APCVD in an Excess of Water Vapour*, Journal of the Electrochemical Society 152(7), F71-74.

4. Progress Reports on International Linkage Award Projects

Magneto-optical imaging of super-current flow in superconducting tapes and wires

Funded: 2004 2005 2006
Project ID: LX0453582
Chief Investigators: Prof. S.X. Dou, A.V. Pan – University of Wollongong
Prof. T.H. Johansen – University of Oslo

This project is aimed at establishing the connections between local and global superconducting current-carrying abilities in magnesium diboride and high temperature superconducting tapes and wires with the help of local high-resolution magneto-optical imaging.

Research exchange activities include the visit of a research fellow, Dr A. V. Pan and a PhD student, M. Rousell from ISEM, UoW to University of Oslo to use the MOI facilities there. Prof T. Johansen visited to ISEM, UoW and gave seminars and conducted collaborative research work as well as jointly prepared the ARC discovery project for next five years.

During the second year of this project, the magnetic flux penetration behaviour has been studied in MgB_2 thin films produced by PLD and the work on MgB_2 superconducting wires has been extended:

We have investigated two MgB_2 thin films produced by pulsed laser deposition. The magneto-optical (MO) imaging technique was used to provide images of the magnetic flux penetration behaviour while the study of the critical current density (J_c) dependence with the applied magnetic field gives information about the global magnetic behaviour of the sample. Atomic force microscopy and scanning electron microscopy images were used as well in order to comprehend the influence of the microstructure on the magnetic properties of the samples. The MO images show that the flux penetration is governed by abrupt vortices avalanches at low temperature while the penetration is gradual at high temperature. Such avalanches are related to the partial flux jumps visible as anomalous noise in the J_c-field curves. In addition, peculiarities in the avalanches in the ex situ were observed and carefully analysed. Such study led to the conclusion that the observed dendrite-like structures are a succession of mesoscopic flux jumps strongly interacting with the microstructural holes scattered in the superconducting film.

Systematic investigation of various Ag-sheathed Bi-2223 tapes produced by the powder-in-tube technique under various final heat treatment conditions has been carried out. The tapes were comparatively studied by local magneto-optical imaging and global techniques. The combination of the complementary local and global results was used for establishing links between microstructure formation mechanisms and superconducting properties. Different measurements indicate that the amount of cracks and the grain connectivity, as well as the critical current density, are very sensitive to the second-step sintering conditions. The experimental data provide reasonably well consistent results, which fully describe the behaviour on macro- and microscopic scales. These facts enable us to single out tape with slow cooling and its fabrication procedure as the most optimal approach, which is consistent with previous studies showing an improvement of the superconducting properties of Bi-2223 tapes with longer annealing time. Furthermore, the tapes investigated exhibited the similarity of the trends extracted from the magnetic critical current density, X-ray diffraction analysis, and transition width measurements. This similarity indicates an important role for pinning induced by the secondary phases and precipitates in the tapes.

1. M Roussel, A V Pan, A.V. Bobyl, T.H. Johansen and S X Dou, "Magnetic flux penetration in MgB_2 thin films produced by pulsed laser deposition", Supercond. Sci. Technol. 18 1391-1395 (2005).

2. M. Roussel, A .V. Pan, R. Zeng, and S. X. Dou, Influence of the final heat treatment on the superconducting properties of Bi-2223 multifilamentary tapes, Physica C 425, 135-143 (2005).

Simulation and Characterisation of opto-thermionic cooling devices

Funded: 2003 2004 2005
Project ID: LX0348004
Chief Investigators: Prof. C. Zhang, A/Prof. R.A. Lewis – University of Wollongong
Prof. K.A. Chao – Lund University, Sweden

Project summary: Opto-thermionic devices combine thermionic emission and laser cooling to achieve the maximum cooling power and highest thermal efficiency. These devices are ultra small, very reliable and fully integratiable. Many important problems need to be solved to improve the performance of this new class of solid-state cooling devices. One is to understand and manipulate the electron-hole radiative recombination and minimize the Auger process in reduced dimensionality devices such as quantum wells. Researchers at Wollongong and Lund will collaborate on theoretical analysis, computer simulation and electrical/optical measurements to solve this problem.

Improvement of critical current density in MgB_2 wire and tapes and Y-Ba-Cu-O coated conductors

Funded: 2005 2006
Project ID: LX0559656
Chief Investigators: X.L. Wang, S.X. Dou, and J.M. Yoo

The Linkage International Fellow, Dr. Jaimoo Yoo, visited the Institute for Superconducting and Electronic Materials at University of Wollongong to undertake research on this project during 1 June 2005 – 14 October 2005. As part of the granted cooperative projects, research work was conducted by both ISEM (Australia) and New Frontier Projects (Korea). These co-operative works, joint publications and exchange of researchers opened opportunities for both sides to enhance research capabilities about MgB_2 superconductor and Y-Ba-Cu-O coated conductors.

On MgB_2 work, MgB_2 powders were synthesised by spray pyrolysis. It was found that the microstructure and average particle size were dependent on solution concentration, pyrolysis temperature and mass flow of carrier gas. The particle size was decreased and became more uniform with decreasing solute concentration in the solution. The MgB_2 tapes with several metal powder additions were fabricated by PIT method with or without heat treatment. The J_c value of 16,000 A/cm^2 at 4.2 K and 5 T were obtained for the MgB_2 tape with 10 vol % of Cu addition without heat treatment. The J_c-B curve shows enhancement in J_c under magnetic field, which suggests enhancement in workability and grain connectivity with several metal powder addition.

For YBCO coated conductors, the process variables of batch-type MOD method were optimised with changing annealing temperature, water partial pressure, and oxygen partial pressure. The window for optimal $P_{(O2)}$ was narrow about 700ppm for batch-type process. YBCO films in batch-type MOD process were optimised at 740~770°C and $P_{(H2O)}$ of 2.3%~7.3%. A new precursor solution for MOD-processing of YBCO coated conductor was synthesised and chemically modified to optimise solution processing parameters. Addition of organic additives to the precursor solution improved the thickness of precursor film and suppressed the aging of precursor solution.

The growth properties of MOD-YBCO films were investigated. Total pressure was changed from 700 torr to 1 torr and its effect on growth of YBCO films was compared with atmospheric one. The lower pressure was effective to control the pore size and also annealing time was shortened. But, the annealing condition was narrow and further optimisation was required to increase the critical current. Biaxially textured metal tapes with low magnetic hysteresis loss have been fabricated by employing multilayer architecture of Ni/Cu and electrodeposition process. Electrochemically fabricated Ni/Cu tape shows low magnetic hysteresis loss and well-established biaxial texture.

1. J.W. Ko, J.M. Yoo, Y.K. Kim, K.C. Chung, S.I. Yoo, X.L. Wang, S.X. Dou,"MgB_2 powder preparation through a spray pyrolysis process" (minor correction for publishing in Physica C)

2. J.W. Ko, J.M. Yoo, Y.K. Kim, K.C. Chung, S.I. Yoo, X.L. Wang, S.X. Dou, "Fabrication of MgB_2 tape with metal powder addition" (submitted in Journal of the Korea Institute of Applied Superconductivity and Cryogenics)
3. 1. J.M. Yoo, Y.K. Kim, K.C. Chung, J.W. Ko, G.W. Hong, H.G. Lee, J.H. Kim, H.S. Chung, X. L. Wang, S. X, Dou, "Chemical Modification of Precursor Solution for Long Length YBCO Coated Conductor Fabrication", EUCAS 2005, 2005.9.11-15, Vienna, Austria.
4 J.M. Yoo, Y.K. Kim, J.W. Ko, K.C. Chung, H.S. Chung, K. Marken, S. Hong, X. L. Wang, S. X, Dou, "Electrodeposition of Biaxially Textured Metal Tape with Low Magnetic Hysteresis Loss for Coated Conductor Application", PACRIM 6, 2005.9.11-16, Maui, USA .

The role of nano-structures for the super-current flow and limitation in high-temperature superconducting films and multi-layers

Funded:	2004	2005	2006	2007
Project ID:	LX0455329			
Australian Investigator:	H. K. Liu			
Partner Investigator:	V. Pan			

The aim of the project is the development of the second generation of high-temperature superconductors for electrical power engineering. The comprehension of critical current density limiting mechanisms in films and multi-layers, as well as the construction of corresponding theoretical models will be the main scientific outcome of the project.

Mutual research visits have been exchanged between the Institute for Metal Physics and University of Wollongong by Prof. Pan and an Early Career Researcher. Seminars were given by corresponding visitors at the host institutions. The thin films samples and their behaviour in magnetic fields and temperatures have been discussed. A new YBCO film deposition approach is attempted by magnetron sputtering and pulsed laser deposition.

New phenomena - peak-effect and angular hysteresis - in field/angle $J_c(H, \theta)$ dependencies are detected for YBCO epitaxial films at moderate dc magnetic fields H parallel to the film. Films (300-350 nm thick) are deposited by off-axis dc magnetron sputtering onto r-cut sapphire substrate buffered with CeO_2. Surface roughness (peak-to-valley) determined by AFM does not exceed 2 nm. $J_c(H, \theta)$-curves are measured by low-frequency ac magnetic susceptibility and four-probe transport technique. $J_c(H)$ at $H||ab$-plane for the most smooth films reveal dome-shape enhancement of J_c(up to 10 p.c.) above $J_c(0)$ value, starting from the field H^* ascribed to the first critical field H_{c1} of thin film. $J_c(H)$-plots at $H||c$-axis with a plateau at low fields followed by monotonic fall-down are consistent to our model of vortex lattice depinning from the out-of-plane linear defect network (growth-induced edge dislocations). Field dependencies of J_C at arbitrary inclination angles may be recalculated from $J_c(H, \theta=0)$ and $J_c(H, \theta=\pi/2)$, assuming independent effects of normal $H\cos\theta$ and parallel $H\sin\theta$ field components on J_c. Angle $J_c(\theta)$−dependencies evolution with H is shown to be consistent with dominant mechanism of pinning on edge dislocations. The most surprising feature of this evolution is the emergence of the peak in $J_c(\theta)$-dependence for $H||c$-direction, becoming observable only above threshold magnetic field H_p dependent on film thickness and surface roughness. Angular hysteresis in $J_c(H, \theta)$ dependence is detected for magnetic field directions close to $H||ab$-plane. This hysteresis is sensitive to magnetic/angular pre-history and together with observed peak-effect at $H||ab$-plane can be understood by account for surface (and/or geometrical) barrier as additional pinning source for Abrikosov vortices.

These results have been reported on 7th European Conference on Applied Superconductivity (Invited report).

V M Pan, S A Pozigun, Yu V Cherpak, V A Komashko, A L Kasatkin, E A Pashitskii, A V Semenov, A V Pan, Peak-effect and angular hysteresis in $J_c(H, \theta)$ dependencies for $YBa_2Cu_3O_{7-\delta}$ epitaxial films, to be published in Inst. Phys. Conf. Ser. (2006 IOP Publishing Ltd).

Selected Abstracts

Dynamic Hall resistivity of electronic systems in the presence of Rashba coupling at zero field, *Chao Zhang and Zhongshui Ma*, Physical Review B **71**, 121307 (2005)

We report a phenomenon in electronic systems. It is shown that, at both zero and finite frequencies, Hall resistivity (ρ_{xy}) is finite in an electronic system with sufficient Rashba coupling and in the absence of an external magnetic field. It is found that the off-diagonal component of the resistivity is determined by the reactive part of the inverse dielectric functions. This is in contrast to any other electrical transport, including magnetotransport where all resistivity components both diagonal and off diagonal are determined by the absorptive part (imaginary part) of the inverse dielectric functions. The longitudinal resistivity (ρ_{xx}) decreases as the Rashba coupling increases. The transverse charge current reported here should be clearly distinguished from the intrinsic transverse spin current reported previously

Electronic efficiency in nanostructured thermionic and thermoelectric devices, *M. F. O'Dwyer, R. A. Lewis, C. Zhang, T. E. Humphrey*, Physical Review B**72**, 205330 (2005)

Advances in solid-state device design now allow the spectrum of transmitted electrons in thermionic and thermoelectric devices to be engineered in ways that were not previously possible. Here we show that the shape of the electron energy spectrum in these devices has a significant impact on their performance. We distinguish between traditional thermionic devices where electron momentum is filtered in the direction of transport only and a second type, in which the electron filtering occurs according to total electron momentum. Such "total momentum filtered" thermionic devices could potentially be implemented in, for example, quantum dot superlattices. It is shown that whilst total momentum filtered thermionic devices may achieve an efficiency equal to the Carnot value, traditional thermionic devices are limited to an efficiency below this. Our second main result is that the electronic efficiency of a device is not only improved by reducing the width of the transmission filter as has previously been shown, but also strongly depends on whether the transmission probability rises sharply from zero to full transmission. The benefit of increasing efficiency through a sharply rising transmission probability is that it can be achieved without sacrificing device power, in contrast to the use of a narrow transmission filter which can greatly reduce power. We show that devices that have a sharply rising transmission probability significantly outperform those that do not and that such transmission probabilities may be achieved with practical single and multi barrier devices. We discuss how the shape of the electron energy spectrum will also have an effect on the electronic efficiency of thermoelectric devices due to mathematical equivalences in the ballistic and diffusive formalisms. Finally, we present an experimental measure that might be used to provide an indication of the nature of the electron energy spectrum and the electronic efficiency of a ballistic device.

Reversible thermoelectric nanomaterials, *T. E. Humphrey and H. Linke*, Physical Review Letters **94**, 096601 (2005)

Irreversible effects in thermoelectric materials limit their efficiency and economy for applications in power generation and refrigeration. While electron transport is unavoidably irreversible in bulk materials, here we derive conditions under which reversible diffusive electron transport can be achieved in nanostructured thermoelectric materials. We provide a fundamental thermodynamic explanation for why the optimum density of states in a thermoelectric material is a delta function and for why inhomogeneous doping and segmentation improve the thermoelectric figure of merit.

Novel Electrode Substrates for Rechargeable Lithium/Polypyrrole Batteries, *J. Wang, C. O. Too, D. Zhou and G.G. Wallace,* J. Power Sources **140,** 162-167 (2005).

A lightweight and inexpensive stainless steel mesh has been investigated as an electrode substrate material for Li/Polypyrrole rechargeable battery. The effects of substrate materials on surface morphology of films, charge-discharge capacity and coulombic efficiency are discussed in detail. The results show that the

capacity of the cell with stainless steel mesh is about 10% lower than the cell using platinum mesh, but it is much lighter and cheaper than that of platinum mesh, therefore, it is a promising substrate material for Li/polymer batteries.

A highly flexible polymer fibre battery, *J. Wang, C. O. Too, and G.G. Wallace*, J. Power Source*s* **150** 223-228 (2005).

The development of highly flexible fibre batteries based on conducting polymer and single-wall carbon nanotubes (SWNTs) is described. Initially, polypyrrole-hexafluorophosphate (PPy/PF_6) and SWNTs were tested in lithium cells to ascertain their performance. Based on the results, fibre batteries consisting of a PPy/PF_6 cathode and an anode based on SWNTs were fabricated and tested in both a "flood cell" and "dry cell", arrangement.

Nonlinear response formula for an interacting two-dimensional electron gas under a magnetic field and microwave radiation. *Tadashi Toyoda, Maho Fujita, Hideki Koizumi, and Chao Zhang,* Physical Review B71, 033313 (2005)

Introducing a canonical transformation of the second quantized field operators for two-dimensional interacting electrons under a uniform static magnetic field and a microwave radiation field, an exact formula that transforms the retarded density response function of the electrons to that of the electrons without the radiation field is derived. The formula provides a new way to treat the effects of the microwave radiation field on the electron density response when the conventional linear response approximation is not applicable.

Solid-state thermionics and thermoelectrics in the ballistic transport regime, *T. E. Humphrey, a_ M. F. O'Dwyer, C. Zhang, and R. A. Lewis*, Journal of Applied Physics **98**, 026108 (2005)

It is shown that the equations for electrical current in solid-state thermionic and thermoelectric devices converge for devices with a width equal to the mean free path of electrons, yielding a common expression for the intensive electronic efficiency in the two types of devices. This result is used to demonstrate that the material parameters for thermionic and thermoelectric refrigerators are equal, rather than differing by a multiplicative factor as previously thought

Effects of collective excitations on the quantum well intersubband absorption, *X. W. Mi***,** *J. C. Cao, C. Zhang***,** *F. B. Meng,* Journal of Applied Physics **98**, 103530 (2005)

The dependence of the intersubband absorption spectra on the Coulomb interaction and quantum well (QW) width is studied. Rather than following the Fermi–Dirac distribution, we have solved the intersubband equations of motion to determine the sub band population self-consistently. We have gone beyond the linear absorption theory to show the effect of various many-body interactions on the absorption spectra. It is found that the redistribution of electrons in excited states reduces the absorption. Our results indicate that the line shape and peak position are determined by the interplay of different collective excitations, such as the Fermi edge singularity and the intersubband plasmon. The dependence of the absorption spectrum on the QW width and the sub band effective masses is also discussed.

A new magnetoplasmon sound wave in a two-dimensional electron gas under electromagnetic radiation, *C. Zhang and S. Hessami Pilehrood,* Europhysics Letters **69**, 663 (2005)

We report a new magnetoplasmon mode and a sound-like collective excitation in two-dimensional electronic systems under a weak magnetic field and a low-frequency electromagnetic radiation. The analysis is based on the exact time-dependent wave functions and the exact relation between response function with and without radiation. The new mode discovered here can be used as a generating mechanism of high-frequency radiation from a system whose characteristic energy is low.

Strong terahertz emission from (100) p-type InAs, *R. Mendis, M. L. Smith, L. J. Bignell, R. E. M. Vickers, and R. A. Lewis* Journal of Applied Physics **98**, 126104 (2005)

Terahertz emission has been observed from (100) Zn-acceptor-doped InAs under illumination by fs pulses of near-infrared radiation. Turning the crystal about the surface normal produces two maxima per rotation, whether the angle of incidence is 45° or 75°, in contrast to (111) p-InAs, where three maxima per rotation have been reported. The emitted terahertz power has a quadratic variation with the pump power and decreases with increasing temperature in the range 20300 K. This behaviour is consistent with a photocurrent surge being the dominant terahertz generating mechanism at low excitation fluences. The p-type InAs generates about two orders of magnitude more power than the standard unbiased terahertz emitter, 1mm thick ZnTe.

Electrochemical synthesis of polypyrrole films using stainless steel mesh as substrate for battery application, *J. Wang, J. Chen, C.Y. Wang, D. Zhou, C. O. Too and G.G. Wallace*, Synth. Met. **153**, 117-120 (2005).

The effect of synthesis conditions of polypyrrole films, using stainless steel mesh as electrode substrate, on the capacity of batteries has been investigated. The polypyrrole films were prepared using different solvents, different polymerisation methods, and different deposition time. The results show that the performance of the cell with stainless steel mesh is similar to the cell using platinum mesh, but stainless steel mesh is lighter and cheaper than that of platinum mesh.

Nano-structured SnO_2-carbon composites obtained by in situ spray pyrolysis method as anodes in lithium batteries, *Ling Yuan, K. Konstantinov, G.X. Wang, H.K. Liu and S.X. Dou*, J. Power Sources **146** 180 (2005).

In this paper, we report on a series of SnO_2-carbon nano-composites synthesised by in situ spray pyrolysis of a solution of $SnCl_2{\cdot}2H_2O$ and sucrose at 700 °C. The process results in super fine nanocrystalline SnO_2, which is homogeneously distributed inside the amorphous carbon matrix. The SnO_2 was revealed as a structure of broken hollow spheres with porosity on both the inside and outside particle surfaces. This structure promises a highly developed specific surface area. X-ray diffraction (XRD) patterns and transmission electron microscope (TEM) images revealed the SnO_2 crystal size is about 5–15 nm. These composites show a reversible lithium storage capacity of about 590 $mAhg^{-1}$ in the first cycle. The discharge curve of the composite indicates that lithium is stored in crystalline tin, but not in amorphous carbon. However, the conductive carbon matrix with high surface area provides a buffer layer to cushion the large volume change in the tin regions, which contributes to the reduced capacity fade compared to nanocrystalline SnO_2 without carbon.

Electrochemical properties of carbon coated $LiFePO_4$ cathode materials, *G.X. Wang, L. Yang, S. Bewlay, J.H. Ahn, J. Yao, H.K. Liu, S.X. Dou*, J. Power Sources **146,** 521 (2005).

Carbon coated lithium iron phosphates were prepared by a carbon aero gel synthesis process, through which $LiFePO_4$ particles were embedded in amorphous carbon. The carbon coating effect can significantly enhance the electronic conductivity of $LiFePO_4$. The electrochemical properties of the as-prepared $LiFePO_4$ cathode materials were systematically characterised. The carbon coated $LiFePO_4$ cathode demonstrated a high capacity and stable cyclability.

Synthesis of nanocrystalline transition metal and oxides for lithium storage, *G.X. Wang, Y. Chen, S. Needham, J.H. Ahn, H.K. Liu, S.X. Dou*, J. Power Sources **146**, 487 (2005).

Nanosize silver and tin dioxide powders were synthesised by novel reverse-micelle technique. The reverse-micelles were formed by micro-emulsion of organic solvents, water based salts and surfactants. The spherical nanosize Ag powders were formed via in-situ reduction. The tin hydroxide precipitation were formed in reverse micelles and converted to tin dioxide nanopowders after heat treatment. The Ag and SnO_2 powders have a particle size in the range of 20 – 50 nm. The as-prepared nanosize Ag and SnO_2 nanopowders were used in lithium-ion cells for lithium storage.

Nanostructured electrode materials for rechargeable lithium-ion battery applications, *G.X. Wang, S. Bewlay, L. Yang, J.Z. Wang, Y. Chen, J. Yao, H.K. Liu and S.X. Dou*, J. Materials Science & Technology **5** 1135 (2005).

Nanocrystalline $LiFePO_4$ and Si-C powders were prepared as electrode materials for lithium-ion batteries. Near full capacity (170 mAh/g) was achieved at the C/8 rate at room temperature for $LiFePO_4$ electrodes. Nanosize Si-C composite anode materials demonstrated a reversible lithium storage capacity of 1450 mAh/g with good cyclability when used as anodes in lithium-ion cells. Nanostructured electrode materials have an important role to play in developing a new generation of lithium-ion batteries that will offer a dramatic improvement in power delivery.

Enhancement of ionic conductivity of PEO based polymer electrolyte by the addition of nanosize ceramic powders, *G.X. Wang, L. Yang, Y. Chen, J.Z. Wang, S. Bewlay and H.K. Liu*, Journal of Nanoscience and nanotechnology **5,** 17 (2005).

The ionic conductivity of polyethylene oxide (PEO) based solid polymer electrolytes (SPEs) has been improved by the addition of nanosize ceramic powders (TiO_2 and Al_2O_3). The PEO based solid polymer electrolytes were prepared by the solution casting method. Electrochemical measurement shows that the 10 wt% TiO_2 PEO-$LiClO_4$ polymer electrolyte has the best ionic conductivity (about 10^{-4} Scm^{-1} at 40 °C – 60 °C). The lithium transference number of the 10 wt% TiO_2 PEO-$LiClO_4$ polymer electrolyte was measured to be 0.47, which is much higher than that of bare PEO polymer electrolyte. A.c. impedance testing shows that the interface resistance of ceramic added PEO polymer electrolyte is stable. Linear sweep voltammetry measurement shows that the PEO polymer electrolytes are electrochemically stable in the voltage range of 2.0 – 5.0 V versus a Li/Li^+ reference electrode.

An investigation of polypyrrole-LiFePO4 composite cathode materials for lithium-ion cells, *G.X. Wang, L. Yang, Y. Chen, J.Z. Wang, S. Bewlay and H.K. Liu***,** Electrochimica Acta **50/24,** 4649 (2005)

A series of polypyrrole-$LiFePO_4$ (PPy-$LiFePO_4$) composites were synthesised by polymerising pyrrole monomers on the surface of $LiFePO_4$ particles. A.C. impedance measurements show that the coating of polypyrrole significantly decreases the charge-transfer resistance of $LiFePO_4$ electrodes. The electrochemical reactivity of polypyrrole and PPy-$LiFePO_4$ composites for lithium insertion and extraction was examined by charge/discharge testing. The PPy-$LiFePO_4$ composite electrodes demonstrated an increased reversible capacity and better cyclability, compared to the bare $LiFePO_4$ electrode**.**

Microstructures and phase evolution in $YBa_2Cu_3O_{7-x}$ films grown on various substrates fabricated via a non-fluorine sol–gel route *A.H. Li, M. Ionescu, H.K. Liu, D.L. Shi, X.L. Wang, X. Peng, and E.W. Collings* Physica C, vol.**426-431**, 1408-14 (2005)

$YBa_2Cu_3O_{7-x}$ films were grown on polycrystalline Ag and single crystalline YSZ, $SrTiO_3$, and MgO substrates using non-fluorine sol–gel and spin coating methods. The effects of heat treatment conditions on the phase evolution and microstructures were investigated using optical microscope, X-ray diffraction, and atomic force microscope. For Ag substrates, Y123 phase started to form at 750 °C and higher sintering temperatures improved the degree of (0 0 1) texture. Mirror-like surfaces without any cracks were achieved for sintering at 750–900 °C. However, voids were observed for films grown on the Ag substrates at temperatures higher than 810 °C and their size and density increased as the temperature increased. For the films grown on single crystal substrates sintered at 800 °C, numerous micro cracks with large crack widths were observed, while cracking is less of a problem for films grown on Ag substrates. Epitaxial films without any cracks were achieved for films grown on single crystalline substrates under optimised conditions. Possible mechanisms for the formation of cracks is discussed.

Structure and magnetism in the oxygen-deficient perovskites $Ce_{1-x}Sr_xCoO_3$. *M. James, K. S Wallwork, R. L. Withers, D. J. Goossen, K. F. Wilson, J. Horvat, X. L. Wang, M. Colella,* Materials Research Bulletin, **40**, 1415 (2005)

We have examined the structure and phase behaviour of strontium-doped $Ce_{1-x}Sr_xCoO_{3-delta}$ and found that the perovskite form is stabilised over a relatively narrow solid solution range (x>0.85). A combination of electron, powder X-ray and neutron diffraction has revealed tetragonal superstructures of the basic perovskite unit; (I4/mmm) $2a_p2a_p4a_p$ (x=0.90) and (P4/mmm) $a_pa_p2a_p$ (x=0.95). Magnetisation

measurements show ferromagnetic behaviour under applied magnetic fields. Low temperature neutron diffraction of $Ce_{0.10}Sr_{0.90}CoO_{2.80}$ in zero field reveals a magnetic cell of dimension $2a_p2a_p4a_p$ with an ordered cobalt moment of 1.7B.M. at 25K. [All rights reserved Elsevier] (30 References).

CMR $La_{0.7}Ca_{0.3}MnO_3$and $La_{0.7}$ $Sr_{0.3}MnO_3$ thin films fabricated by sol-gel method, *X. Z. Cheng. H. F. Zhen, A. H. Li. X. L. Wang, H. Kimura,* Journal of Crystal Growth, **275** (1-2), e2415 (2005).

Sol-gel precursors for $La_{0.7}Ca_{0.3}MnO_3$ and $La_{0.7}Sr_{0.3}MnO_3$ were made from La, Ca, Sr and Mn acetates with a mixture of 2-ethylhexanoic acid and 2-methxyethanol in a ratio of 2:1 as solvent. With these precursor solutions, $La_{0.7}Ca_{0.3}MnO_3$ and $La_{0.7}Sr_{0.3}MnO_3$ thin films were deposited on YSZ and MgO substrates, respectively, by spin coating and sintering at different temperatures. X-ray diffraction (XRD) patterns show that these thin films consist of pure $La_{0.7}Ca_{0.3}$ MnO_3 and $La_{0.7}Sr_{0.3}MnO_3$ phases. Atomic force microscope images of the thin films show uniformly developed grains and the development of the grains with rising sintering temperature. EDS analysis shows that the composition of grains of $La_{0.7}Ca_{0.3}MnO_3$ thin films is in accordance with the composition of the precursor sol-gel. Magnetisation measurements of the fabricated films show typical ferromagnetic order transitions. Conductivity measurements at zero magnetic field show that all the films have typical semiconductor to conductor transitions, and magnetoresistance was demonstrated after a magnetic field was applied. [All rights reserved Elsevier] (16 References).

Structure, spin glass, and spin state in perovskite GdCo1-xMnxO3, *M.M Farhoudi,X. L. Wang,* Magnetics, IEEE Transactions on **41**, 3493 (2005)

Perovskite GdCo/sub 1-x/Mn/sub x/O/sub 3/ (x=0.2,0.3,0.4,0.5) compounds have been prepared by solid-state reaction. Structures were characterised using X-ray diffraction and Rietveld Refinement method. The compounds crystallised in orthorhombic with Plmn space group. Crystal lattices decreased with the increase of Mn doping level. DC magnetisation and ac susceptibility were studied over a wide temperature range and different frequencies. A typical spin glass state was observed in all samples around the same temperature of 122 K where the compounds turned from paramagnetic to ferromagnetic states. For x<0.5, secondary transitions were observed both in dc and ac measurement which were independent of frequency but depended on doping level. The valences of Co or Mn with possible spin states were estimated.

Infrared-active phonons of perovskite $HoMn_{1-x}Co_xO_3$(x=0--0.8), *F. Gao, X. L. Wang, M. M. Farhoudi, R. A. Lewis,* Magnetics, IEEE Transactions on **41,** 2763 (2005)

Polycrystalline perovskites compounds $HoMn_{1-x}Co_xO_3$ (x= 0-0.8) have been prepared by conventional solid state reaction. Here we used Far-infrared (FIR) spectroscopy to study infrared active phonon modes and present a comparative analysis of infrared transmission spectra of polycrystalline $HoMn_{1-x}Co_xO_3$ (x= 0-0.8). The data indicated that phonon modes significantly changed with the increase of the cobalt doping level. Four main bands were assigned as external, torsional, bending and stretching bands. The external vibration energy remain same at ω_1~190 cm^{-1} for Co doping $x \leq 0.5$ and shift to higher energy for x >0.5. Torsional and bending bands exhibit splitting. Stretching bend is at 600 cm^{-1} for all samples, but the band width is reduced as Co doping increased. The transmission spectrum of $HoMn_{4/5}Co_{1/5}O_3$ was analysed to the spectrum of optical density. The minimum number of oscillators to obtain a reliable fit is 5 by using a sum of non interacting harmonic oscillators.

Absence of ferromagnetism and strong spin-orbital coupling in polycrystalline in and Co codoped $Zn_{1-x}In_xCo_{0.075}In_xO$ oxide, *G. Peleckis, X. L. Wang, S. X. Dou,* Magnetics, IEEE Transactions on, **41**, 2739 (2005)

Polycrystalline samples of In and Co codoped ZnO ($Zn_{1-x}In_xCo_{0.075}O$; 0.010<x<0.020) oxide were prepared by solid-state synthesis technique. Phase purity and structure refinement done by means of the Rietveld analysis technique shows that both Co and In substitute properly into Zn positions. In doping, increased bulk conductivity of the samples at room temperature indicates an increase of charge carrier concentration. All samples showed paramagnetic behaviour following Curie-Weiss law at close to room temperatures, with short range antiferromagnetic interaction with $\Theta \approx$ -200 K. Effective magnetic moment (μ_{eff}) calculations showed a strong orbital contribution to the value of μ_{eff}, increasing with an increase of In content (x).

Co valence by K-edge X-ray absorption spectroscopy, magnetic properties, and structure of polycrystalline bulk $Zn_{1-x}Co_xO$, *G. Peleckis, X. L. Wang, R. S. Liu, S. X. Dou*, Magnetics, IEEE Transactions on, **41**, 2727 (2005)

We report on magnetic properties and a Co K-edge X-ray absorption spectroscopy (XAS) study of polycrystalline bulk $Zn_{1-x}Co_xO$ (x=0.10,0.15,0.17) samples. All samples show paramagnetic behaviour and no ferromagnetism was observed. XAS results showed that for all samples the valence of Co is 2+. Spin state assessment derived from Currie-Weiss fitting indicated a possible spin state transition from Co^{2+} high spin to Co^{2+} low spin. Calculated μ_{eff} values for samples with x=0.10 and 0.15 indicated an orbital contribution to the effective magnetic moment of the Co ion.

Magnetic and transport properties of the layered perovskite system $Sr_{2-y}Y_yCoO_4$ (0<y<1), *X. L. Wang, E. Takayama-Muromachi,* Physical Review B**72**, 64401(2005)

Layered perovskite cobalt oxides $Sr_{2-y}Y_yCoO_4$ (y=0, 0.1, 0.3, 0.5, 0.67, 0.83, and 1) were synthesised under high pressure and high temperature conditions. Structure refinement revealed that these compounds crystallize in K_2NiF_4-type structures with space group I4/mmm. The parent compound Sr_2CoO_4 undergoes a ferromagnetic transition with T_c=255 K. The T_c decreases with increasing y to 150 K for y=0.5, and ferromagnetism was not observed for y>=0.67. Assessment of spin states for Co^{3+} and Co^{4+} ions suggested strongly that both are present as intermediate spin states when y<=0.67 at least for the higher temperature range above T_c. Fairly large negative magnetoresistance was observed for Sr_2CoO_4 in the vicinity of T_c and in the lower temperature region (28 References).

Microstructures and enhancement of critical current density in $YBa_2Cu_3O_7$ thin films grown by pulsed laser deposition on various single crystal substrates modified by Ag nano-dots, *A. H. Li, M. Ionescu, H. K. Liu, T. Silver, X. L. Wang, S. X. Dou*, IEEE Transactions on Applied Superconductivity, **l.15**, no.2, pt.3, 3046-9 (2005).

$YBa_2Cu_3O_7$ (Y123) thin films were grown by pulsed laser deposition (PLD) on YSZ (100), SrTiO3 (100), and LaAlO3 (100) single crystal substrates. Prior to the film deposition, a discontinuous layer of Ag nano-dots was deposited on the substrates. The Y123 films grown on such surfaces modified with Ag nano-dots were characterised by Atomic Force Microscopy (AFM), X-ray diffraction (XRD), scanning electron microscopy (SEM), AC susceptibility and DC magnetisation. The effects of the density of Ag nano-dots, which was controlled by the numbers of PLD shots, on the microstructures and resultant critical current density J_c have been studied systematically. Results showed that at fixed physical deposition conditions J_c increased monotonically with number of Ag shots, n, for films grown on both STO and LAO substrates. At 77 K, the J_c increased from 10^6 to 3.210^6 A/cm^2 for LAO and from 810^5 to 3.5106 A/cm^2 for STO as n increased from 0 to 150. At 5 K, the enhancement of J_c was approximately four times at both low and high fields. However, for films grown on YSZ substrate, J_c increased from 210^5 to 210^6 A/cm^2 as Ag shots increased from 0 to 30, and decreased to 910^5 for n>=60. Detailed microstructure investigations indicated that the crystallinity and ab alignment gradually improved as the number of Ag-nano-dots increased.

Dynamical hysteresis V-I curves of superconductors, *X. B. Xu, L. Zhang, S. Y. Ding, X. Leng, Z. H. Wang, X. L. Wang*, Superconductor Science & Technology **18**, 758-62 (2005)

We study the dynamical hysteresis of transport V -I characteristics based on the flux creep model characterised by flux diffusion speed $v = v_0(j/j_c)|j/j_c|^n$. It is shown that there are two sorts of hysteresis loops in the V -I curve: clockwise and anticlockwise. The clockwise loop can be observed if v is lower by far than the speed of the applied current v_a (dI/dtd, where d is the sample thickness): $v<<v_a$. This formula predicts that it is very difficult to observe the V -I loop in a thin film because of its small d. Furthermore, the clockwise loop could always be observed if the critical current of the sample increases with time, whereas the anticlockwise loop could only be explained by the critical current decreasing with time, no matter which mechanism is responsible for the critical current's change. The numerical results could be used to understand experiments on a variety of samples.

Vector characterisation of soft magnetic materials, *Z. W. Lin, H. W. Lu, J. G. Zhu, J. J. Zhong, X. L. Wang, S. Y. Ding,* Journal of Applied Physics **97**, 10R306-1-3 (2005).

A three-dimensional (3D) magnetic property testing system has been completed and successfully used to measure 3D hysteresis loci of soft magnetic material. This paper presents the techniques to characterise soft magnetic materials under 3D magnetic excitations in detail. Using three couples of excitation coils controlled by a computer to generate the magnetic fields in three orthogonal axes, various types of flux density loci, such as circular or elliptical rotating vectors of flux density with any given orientations in 3D space, can be obtained. Based on 3D finite element analysis and a comparative study, a sandwich arrangement comprising a sample, guard pieces, and search coils with double-layer structure was proposed. Compared with the conventional surface search coils, this arrangement can significantly improve the accuracy of measurement. The comprehensive calibration process and the experimental results of the 3D hysteresis loci of soft magnetic composite materials are also presented.

Synthesis, structures, and magnetic properties of novel roddlesden-popper homologous series $Sr_{n+1}Co_nO_{3n+1}$ (n=1,2,3,4, and ∞;), *X. L. Wang, . H. Sakurai, E. Takayama-Muromachi,* Journal of Applied Physics, **97,** 10M519-1-3 (2005).

Roddlesden-Popper homologous series $Sr_{n+1}Co_nO_{3n+1}$ (n=1,2,3,4, and) compounds were successfully synthesised by a high pressure and high temperature technique. Structure refinement revealed that these compounds crystallise in tetragonal structures, while the compound n= is cubic. These compounds are ferromagnetic with the Curie temperature decreasing from 255 K for n=1 to about 200 K for n=2-4 and down to 175 K for $SrCoO_3$. Co^{4+} ions present as intermediate spin states for n=1-4, but in the low spin state in $SrCoO_3$. Negative magnetoresistance was observed for Sr_2CoO_4 and found to be larger than that for SrCoO .

Thermally assisted flux flow and individual vortex pinning in $Bi_2Sr_2Ca_2Cu_3O_{10}$ single crystals grown by the travelling solvent floating zone technique, *X. L. Wang XL. A. H. Li, S. Yu, S. Ooi. K. Hirata, C. T. Lin, E. W. Collings,. M. D. Sumption, M. Bhatia, S. Y. Ding, S. X. Dou,* Journal of Applied Physics **97,** 10B114-1-3 (2005).

Magnetoresisitivity and critical current density J_c as a function of temperature and field are studied for $Bi_2Sr_2Ca_2Cu_3O_{10}$ single crystals grown using the travelling solvent floating zone technique. Below a characteristic field B^*, J_c as a function of field exhibits a field-independent plateau associated with thermally activated pinning of individual vortices. Analysis of resistive transition broadening revealed that thermally activated flux flow is found to be responsible for the resistivity contribution in the vicinity of T_c. The activation energy U_0 is 800 K in low field, scales as $B^{-1/6}$ for B<2 T and drops to 200 K with $B^{-1/2}$ for B>2 T.

Potential application of solid electrolyte P11OH in Ni/MH batteries, *C.Y. Wang, J. Sun, H.K. Liu, S.X. Dou, D.R. Macfarlane and M. Forsyth*, Synthetic Metals **152** 57–60 (2005)

N,N-Dimethypyrrolidoium hydroxide (P11OH) with polymer poly(tetramethyl ammonium acrylate) (PTMA) was investigated as an electrolyte in Ni-MH cells. The efficiency and the performance of the electrolyte was discussed and elucidated with the performance of the cell. Their electrochemical characteristics at different temperatures (25°C and 50°C) and different discharge current (15 mA/g and 30 mA/g) were investigated. The results show that the cell with electrolyte polymer-P11OH is dischargeable at these temperatures, and a discharge capacity of 142 mAh/g at 25°C was obtained.

Improvement of critical current density and thermally assisted individual vortex depinning in pulse-laser-deposited YBCO thin films on $SrTiO_3$ (100) substrate with surface modification by Ag nanodots, *A.H. Li, H.K. Liu, M. Ionescu, X.L. Wang, S.X. Dou, E.W. Collings, M.D. Sumption, M. Bhatia, Z.W. Lin, J.G. Zhu*, Journal of Applied Physics **97**, 10B107 (2005)

YBCO films were fabricated by pulsed laser deposition on $SiTiO_3$ (100) single-crystal substrates whose surfaces were modified by the introduction of Ag nanodots. J_c was found to increase with the number of Ag shots. Zero-field magnetic J_{co} at 77K increased from 8×10^5 up to 3.5×10^6 A/cm^2 as the number of Ag shots increased from 0 to over 150 times. Microstructure investigations indicated that the crystallinity and the ab alignment gradually improved as the number of Ag nanodots increased. Thermally activated depinning of individual vortices is suggested.

Third harmonics due to surface barrier in high temperature superconductor, *X.B. Xu, L. Zhang, X. Leng, S.Y. Ding, H.K. Liu, X.L. Wang, S.X. Dou, Z.W. Lin, J.G. Zhu*, Journal of Applied Physics. **97**, 10B105 (2005)

The influence of surface barrier on the third harmonic ac susceptibility is studied numerically. The surface barrier is described by a critical current density in surfaces which are higher than the inside one. The model can act as the critical state one, the flux creep one, or the flux flow one when temperature (or field) changes. The numerical results based on the model are more close to the popular experimental data probing the harmonics as a function of temperature (or field). Besides, the surface barrier will lead to new peaks in the real and imaginary parts of the third harmonics, which are the finger signature of the surface barrier. Comparison of the peaks with those of the real part of elemental harmonic shows that they are located at the same temperature where dips in χ' caused by the surface barrier occur, which is in well agreement with experiments.

Non-aqueous synthesis of crystalline Co_3O_4 powders using alcohol and cobalt chloride as a versatile reaction system for controllable morphology, *Z.W. Zhao, Z.P. Guo, H.K. Liu*, Journal of Power Sources **147** (2005) 264–268

Crystalline Co_3O_4 powders with controllable morphology have been prepared using cobalt chloride and various alcohol precursors at different temperatures. The non-aqueous precursor is examined by simultaneous differential thermal analysis (DTA) and thermogravimetric analysis (TGA), and the obtained powders are characterised by X-ray diffraction (XRD) and scanning electronic microscopy (SEM). Co_3O_4 particles demonstrate a dramatic tetragonal dipyramid structure when synthesised from benzyl alcohol and cobalt chloride. A stable and reversible storage capacity for lithium of 740 mAh g−1 within 50 cycles is achieved on electrochemical performance testing.

Electrochemical performance of SnSb and Sn/SnSb nanosize powders as anode materials in Li-ion cells, S.A. Needham, **G.X. Wang, H.K. Liu**, Journal of Alloys and Compounds **400** 234–238 (2005)

Nanosized pure SnSb and SnSb with excess ductile Sn (referred to as Sn/SnSb) powders have been synthesised by careful reductive co-precipitation in NaBH4. Crystallite sizes for both powders measure in the 50–100 nm range with particles agglomerating up to a few micrometers in pure SnSb powder and several tens of micrometers in the Sn/SnSb composite. Pristine powders were mixed separately with carbon black in order to improve dispersion and electronic conduction. Electrodes were constructed using the powders and tested as Li-ion half cell in order to measure the electrochemical performance. The energy storage capacity of electrodes improved in excess of 50% by increasing quantity of carbon black from 20 wt.% to 50 wt.%. Capacity fade over repeated charge and discharge cycles still remains a challenge to practical application of SnSb and Sn/SnSb alloy electrodes.

Single wall carbon nanotube paper as anode for lithium-ion battery, *S.H. Ng, J. Wang, Z.P. Guo, J. Chen, G.X. Wang, H.K. Liu*, Electrochimica Acta **51** 23–28 (2005)

"Free-standing" single wall carbon nanotube (SWNT) papers have been synthesised by simple filtration method via positive pressure. A conventional SWNT slurry coated electrode was fabricated to compare with the SWNT papers. The results show that the capacity of the "Free-standing" electrode was slightly lower than that of the conventional electrode, but the "Free-standing" electrode was produced without any binder, and metal substrate, so that the weight of electrode was reduced significantly. On the other hand, the procedures for SWNT electrode preparation were simplified, so the cost of the manufacturing could be reduced.

The effect of nanoscale Fe doping on the superconducting properties of MgB_2, *S X Dou, S Soltanian, Y Zhao, E Getin, Z Chen, O Shcherbakova, J Horvat,* Superconductor Science and Technology, Vol **18**(5), 710-715 (2005)

Iron is an important sheath material for fabrication of MgB_2 wires. However, the effect of Fe doping on the superconducting properties of MgB_2 remains controversial. In this work, we present results on nanoscale Fe particle doping in MgB_2. The Fe doping experiments were performed using both bulk and thin film forms.

Neither free Fe particles nor FeB compound was detected at 1% Fe doping by means of either transmission electron microscopy (TEM) or x-ray diffraction (XRD), suggesting that Fe substituted for Mg in the lattice. The level of Fe substitution for Mg is estimated to occur at a level lower than 1% of Mg, and this substitution is proposed to be responsible for the decrease in transition temperature with Fe doping. Because of the high reactivity of nanoscale Fe particles, Fe doping is largely in the form of FeB at a Fe doping level of 2% while Fe_2B was detected at 10% Fe doping by means of both XRD and TEM. The $J_c(H)$ performance was severely depressed at above a 2% doping level. The detrimental effect of nanoscale Fe doping on $J_c(H)$ is attributable to both the Fe substitution for B in the lattice structure and the inclusions of Fe and FeB which act as weak links at grain boundaries.

The relevance of the self-field for the 'peak effect' in the transport J_c(H) of iron-sheathed MgB_2 wires, *J Horvat, S Soltanian, W K Yeoh,* Superconductor Science and Technology **18**, 682-688, (2005)

A ferromagnetic sheath around a superconducting wire results in an unusual transport $J_c(H)$. For the field perpendicular to the current, there is a plateau in $J_c(H)$ at high temperatures and intermediate fields. This plateau develops into a peak at lower temperatures—resembling a 'peak effect'. A model based on cancellation of the self-field of the current and the external field within the iron sheath was proposed for the explanation of the plateau in $J_c(H)$. We tested this model in three key experiments. Firstly, we showed that the form of $J_c(H)$ for round MgB_2/Fe wires is strongly temperature dependent. This is in contradiction with the model, because the properties of the iron sheath do not change in the measured temperature range . However, the temperature dependence of J_c might still account for the change of $J_c(H)$. Secondly, the model requires a substantial component of the self-field to be parallel to the external field. Our measurements of $J_c(H)$ for a field parallel to the current show a peak in $J_c(H)$ at high temperatures and a pronounced plateau at low temperatures. The model cannot explain this because the self-field and external field are perpendicular in this experiment. Thirdly, the iron sheath was made thinner on one side of the wire, which should produce an asymmetry in $J_c(H)$ in the model for two different orientations of the external field. Such asymmetry was not observed. These experiments show that the effect of the self-field is of much lower importance than an as yet unknown effect that results in the observed plateau and peak in $J_c(H)$. Such an effect is likely to be based on a specific interaction between the superconductor and ferromagnet, perhaps similar to the overcritical state effect.

Interaction between superconductor and ferromagnetic domains in iron sheath: Peak effect in MgB_2/Fe wires, *J Horvat, W K Yeoh, L M Miller,* Applied Physics Letters, **87**, 102503 (2005)

Interaction between the superconductor and ferromagnet in MgB_2/Fe wires results in either a plateau or a peak effect in the field dependence of transport critical current, $I_c(H)$. This is in addition to magnetic shielding of external field. Current theoretical models cannot account for the observed peak effect in $I_c(H)$. This letter shows that the theoretical explanation of the peak effect should be sought in terms of interaction between superconductor and magnetic domain structure, obtained after the remagnetisation of the iron sheath by the self-field of the current. There is a minimum value of critical current, below which the remagnetisation of the iron sheath and peak effect in $I_c(H)$ are not observed.

YBCO coated conductor using biaxially textured clad composite Ni-Mn/Ni-Cr substrate, *D Q Shi, S X Dou, R K Ko, J K Chung, H S Kim, H S Ha, K J Song, C Park,* Superconductor Science and Technology, **18**, 1405 (2005)

A new biaxially textured composite tape of Ni–4.5% Mn/Ni–1.5% Cr was used as a substrate for a YBCO coated conductor through the RABiTS approach. Multi-layer CeO_2/YSZ/Y_2O_3 buffer layers and YBCO film were deposited on the substrate by pulsed laser deposition. The deposition conditions of the buffer layers and the YBCO were studied and compared. Good biaxial textures have been obtained for buffer layers on composite Ni–4.5% Mn/Ni–1.5% Cr substrates. Scanning electron microscopy on sample cross-sections was used to examine the interface and diffusion of oxygen. The uniform formation of an Ni–Mn–O layer between NiO and the Ni–4.5% Mn layer was observed, and the Ni–Mn–O layer restricted the further growth of NiO layer, which was thin and not continuous, within the coated conductor during YBCO deposition at higher temperature and higher oxygen pressure. The J_c of YBCO films on these metal substrates was 1.5×10^6 A cm^{-2} at 77 K, 0 T.

Off-axis MgB_2 films using an in-situ annealing pulsed laser deposition method, *Y Zhao, M Ionescu, J Horvat, S X Dou,* Superconductor Science and Technology **18**, 395 (2005)

Highly smooth and *c*-axis oriented superconducting MgB_2 thin films were prepared by pulsed laser deposition (PLD) with off-axis geometry. The films were deposited on Al_2O_3–C substrates perpendicularly aligned to a stoichiometric MgB_2 target in a 120 mTorr high purity Ar background gas. An *in situ* annealing was carried out at 650 °C for 1 min in a 760 Torr Ar atmosphere. Despite the short annealing time, an x-ray θ–2θ scan shows fairly good crystallisation, according to the clear *c*-axis oriented peaks for the films. Both atomic force microscopy and the x-ray diffraction results indicate that the crystallite size is less than 50 nm. The root mean square roughness of our off-axis film is ~4nm in a 5 × 5 μm^2 area. The $T_{c\,onset}$ value of the best off-axis film reaches 33.1 K with a narrow transition width of 0.9 K. The films showed no anisotropy in $H_{c\,2}$–T curves when parallel and perpendicular fields were applied. The slope of the $H_{c\,2}$–T curves in the low field regime is 1 T K^{-1}, which is among the highest reported values.

Large upper critical field and irreversibility field in MgB2 wires with SiC additions, *M D Sumption, M Bhatia, M Rindfleisch, M Tomsic, S Soltanian, S X Dou,* E W Collings, Applied Physics Letters **86,** 092507, (2005)

Resistive transition measurements are reported for MgB_2 strands with SiC dopants. The starting Mg powders were 325 mesh 99.9% pure, and the B powders were amorphous, 99.9% pure, and at a typical size of 1–2 μm. The SiC was added as 10 mol % of SiC to 90 mol % of binary MgB_2 [(MgB2)0.9(SiC)0.1]. Three different SiC powders were used; the average particle sizes were 200 nm, 30 nm, and 15 nm. The strands were heat treated for times ranging from 5 to 30 min at temperatures from 675 °C to 900 °C. Strands with 200 nm size SiC additions had $\mu_0 H_{irr}$ and B_{c2} which maximized at 25.4 T and 29.7 T after heating at 800 °C for 30 min. The highest values were seen for a strand with 15 nm SiC heated at 725 °C for 30 min which had a $\mu_0 H_{irr}$ of 29 T and a B_{c2} higher than 33 T.

Effect of heating rates on superconducting properties of pure MgB2, carbon nanotube- and nano-SiC-doped in situ MgB2/Fe wires, *S K Chen, K S Tan, B A Glowacki, W K Yeoh, S Soltanian, J Horvat, S X Dou,* Applied Physics Letters, **87**, 182504, (2005)

The influence of heating rates and annealing temperatures on the transition temperatures (T_c) and critical current densities (J_c) of pure MgB_2, carbon nanotube- and nano-SiC-doped *in situ* monofilamentary MgB_2/Fe wires was investigated. It was found that higher J_c was obtained for pure MgB_2 samples when heat treated with slower heating rates. SiC-doped samples also have higher J_c with slower heating rates, but the J_c is less sensitive to annealing temperatures. However, the J_c of the carbon nanotube-doped wire was found to be insensitive to heating rates. The variation in T_c and J_c with heating rate, and the different behaviours of differently doped MgB_2/Fe wires, make it essential to carefully select the optimum heating rates for heat treatment.

Magnetoresistive effects in Bi-2212 melt textured bulk with MgO additions, *B Winton, M Ionescu, T Silver, S X Dou***,** Journal of Physics D: Applied Physics **38**(14), 2327 (2005)

The magnetoresistive (MR) effect in Bi-2212+MgO composites with proportions 6, 15 and 20 wt% of MgO was observed and compared with the MR effect of pure Bi-2212 and previously reported Bi-2212+USr_2CaO_6. The resistivity of melt textured Bi-2212+MgO composites is characterised by a high sensitivity to an applied magnetic field over an increasing temperature range with increasing MgO addition. X-ray results show that the MgO phase is compatible with the Bi-2212 matrix, stable during the melt texturing process and shows little adverse effect on the superconducting transition temperature. A cryogenic sensor was built using Bi-2212+20 wt% MgO as an active component and tested at 77 K in cycling fields from 0 to 1 T. It showed a high sensitivity and no hysteresis.

Effect of Carbon Nanotube size on superconductivity Properties of MgB2, *W K Yeoh, J Horvat, S X Dou, P Munroe,* IEEE Transactions on Applied Superconductivity **15**, 3284 (2005)

Experimental results are presented for the incorporation of carbon nanotube in polycrystalline MgB_2 superconductor based on X-ray diffraction and transmission electron microscopy measurements. Electron

microscopy studies show that nanotubes are embedded into the MgB_2 matrix with a fraction of nanotubes found to be unreacted and entangled. In contrast, magnetisation measurements indicate a change in the critical current density with the length of nanotubes and not with their outside diameter. This implies that longer nanotubes tend to entangle, preventing their homogenous mixing with MgB_2 and dispersion. Overall, carbon nanotube doping of MgB_2 enhanced the critical density and depressed the critical temperature.

Effect of Nano-Particle Doping on the Upper Critical Field and Flux Pinning in MgB_2, *S X Dou, S Soltanian, W K Yeoh, Y Zhang,* IEEE Transactions on Applied Superconductivity, **15,** 3219 (2005)

The effect of nano particle doping on the critical current density ofMgB_2 is reviewed. Most nano-particle doping leads to improvement of $J_c(H)$ performance while some shows a negative effect as with Cu and Ag. Nano-carbon containing dopants have two distinguishable contributions to the enhancement of J_c field performance: increase of upper critical field and improvement of flux pinning. Among all the dopants studied so far, nano SiC doping showed the most significant and reproducible enhancement in $J_c(H)$. The nano SiC doping introduced many precipitates at a scale below 10 nm, which serve as strong pinning centres. Jc for the nano SiC doped samples increased by more than an order of magnitude at high fields and all temperatures compared to the undoped samples. The significant enhancement in $J_c(H)$ of nano-SiC doping has been widely verified and confirmed, having a great potential for applications. An attempt is made to clarify the controversy on the effects of nano Fe and Ti doping on J_c.

High transport critical current density and large H_{c2} and H_{irr} in nanoscale SiC doped MgB_2 wires sintered at low temperature, *S. Soltanian, X. L. Wang, J. Horvat, S. X. Dou, M. D. Sumption, D. Bhatia, E. W. Collings, P. Munroe and M. Tomsic*, Supercond. Sci. Technol. **18** , 658 (2005)

We report a systematic study on the effect of sintering temperature on the phase formation, critical current density, upper critical field and irreversibility field of nanoscale SiC doped MgB2. Bulk and Fe sheathed wires doped with different nano-SiC particle sizes have been made and heat treated at temperatures ranging from 580 to 1000 degrees C. A systematic correlation between the sintering temperature, normal state resistivity, RRR, J(c), H-c2, and H-irr has been found in all samples of each batch. Samples sintered at a lower temperature have a very fine and well consolidated grain structure while samples sintered at a high temperature contain large grains with easily distinguishable grain boundaries. Low temperature sintering resulted in a higher concentration of impurity precipitates, larger resistivity, higher J(c) up to 15 T and lower T-c values. These samples show higher H-c2 and H-irr at T near T-c but lower H-c2 near T = 0 than samples sintered at high temperature. It is proposed that huge local strains produced by nano-precipitates and grain boundary structure are the dominant mechanism responsible for higher H-c2 at T near T-c. However, higher impurity scattering due to C substitution is responsible for higher H-c2 in the low temperature regime for samples sintered at a higher temperature. In addition to high H-c2, it is also proposed that the large number of nano-impurities serve as pinning centres and improve the flux pinning, resulting in higher J(c) values at high magnetic fields up to 15 T.

Influence of the final heat treatment on properties of Bi-2223 multifilamentary tapes, *M. Roussel, A.V. Pan, R. Zeng, S.X. Dou*, Physica C **425**, 135–143 (2005).

A set of Ag-sheathed Bi-2223 ($Bi_{1.72}Pb_{0.34}Sr_{1.85}Ca_{1.99}Cu_3O_x$) tapes was produced using the powder-in-tube technique under various final heat treatment conditions. These tapes were comparatively studied by ‘‘local’’ (magneto-optical imaging) and ‘‘global’’ (X-ray diffraction, magnetisation and transport measurements) techniques. The combination of the complementary ‘‘local’’ and ‘‘global’’ results was used for establishing links between microstructure formation mechanisms and superconducting properties. Different measurements indicate that the amount of cracks and the grain connectivity, as well as the critical current density, are very sensitive to the second-step sintering conditions. The best results with respect to microstructural and superconducting properties are obtained when the sample is slowly cooled down after the first step sintering at 825ºC.

Magnetic flux penetration in MgB_2 thin films produced by pulsed laser deposition, *M. Roussel, A. V. Pan, A. V. Bobyl, Y. Zhao, S. X. Dou, and T. H. Johansen***,** Supercond. Sci. Technol. **18,** 1391–1395 (2005)

Two types of MgB2 thin films produced by pulsed laser deposition with different *in situ* and *ex situ* sintering routes have been studied. Using the magneto-optical (MO) imaging technique, the magnetic flux penetration behaviour in the films has been investigated. In the case of the *in situ* film, the MO observations reveal conventional flux jumps below the corresponding threshold temperature, whereas in the case of the *ex situ* film the flux jumps appear to take the form of unusual, structurally driven 'blob'-like patterns. The underlying structural features of the films have been investigated by scanning electron and atomic force microscopy. The critical current density dependence on applied magnetic field obtained from magnetisation measurements is consistent with the local behaviour of the magnetic flux, as well as with flux pinning properties expected from the obtained crystalline structure of the *ex situ* film and the amorphous-like surface of the *in situ* film. On the basis of these structural and electromagnetic observations, a mechanism for the structurally driven, spatially reproducible flux jumps is proposed.

Superconducting and Microstructural Properties of two types of MgB2 Films Prepared by Pulsed Laser Deposition, *Y Zhao, M Ionescu, M Roussel, A V Pan, J Horvat, S X Dou*, IEEE Transactions on Applied Superconductivity **15**, 3261 (2005)

Significant differences in superconducting and microstructural properties between two types of MgB_2 films prepared by pulsed laser deposition were determined. A very high H_{c2} -- T slope of 1.1 T/K was achieved in the *in situ* film. The J_c –H curves of the *in situ* film also show a much weaker field dependence than that of the *ex situ* film. The magneto-optical (MO) images show that at 4 K the flux penetrates the *in situ* MgB_2 film through random paths, while for the *ex situ* film, the flux penetration pattern is mostly repeatable, indicating a defect-controlled flux penetration. Microstructural study (transmission electron microscopy and atomic force microscopy) revealed a relatively big grain size in the *ex situ* film. The correlation between the superconducting properties, microstructure and preparation conditions is discussed with regard to the two types of films.

An alternative method for determination of the lock-in angle in twinned superconductors, *L. Shocat, J Horvat, A Pan, M Qin,* Journal of Applied Physics **99**, 043904 (2005)

An alternative method for determining the lock-in angle φ_L for pinning of the vortices on extended defects has been developed. This method does not require any preassumed criterion for defining φ_L Highly twinned $Sm_{1+x}Ba_{2-x}Cu_3O_{6+y}$ single crystal was used for demonstrating the method. Appropriate scaling of the hysteresis loops measured for different angles between the field and twin planes in highly twinned SmBaCuO single crystal led to a clear discrimination between two vortex dynamics regimes. From this scaling, the lock-in angle was determined to be 6°±0.1° for the single crystal investigated. This method significantly reduces the uncertainty in determining the lock-in angle when compared to all the other currently employed methods.

Magneto-optical determination of the properties of hole states in polar semiconductors, *R. A. Lewis, Y.-J. Wang,* Physical Review B**71**, 115211 (2005).

Far-infrared absorption spectroscopy in magnetic fields of up to 30 T of the zinc acceptor impurity in indium phosphide has revealed for the first time a series of free-hole transitions (Landau-related series) in addition to the familiar bound-hole transitions (Lyman series) as well as hitherto unobserved phonon replicas of both series. Analysis of these data permits the simultaneous direct experimental determination of (i) the hole effective mass, (ii) the species-specific binding energy of the acceptor impurity, (iii) the absolute energy levels of the acceptor excited states of both odd and even parity, (iv) more reliable, and in some cases the only, g factors for acceptor states, through relaxation of the selection rules for phonon replicas, and (v) the LO phonon energy. The method is applicable to other semiconductors and may lead to the reappraisal of their physical parameters.

Magnetopolaron interactions in n-type indium phosphide, *R. A. Lewis, P. E. Simmonds, Y.-J. Wang,* Physical Review B**72**, 245207 (2005).

Broadband far-infrared absorption spectroscopy is used to investigate *n*-type indium phosphide in magnetic fields of up to 30 T. The large energy range 2–14 Ry and the large magnetic field range 0 3 employed permit the observation of a rich variety of magnetopolaron interactions. We report on the Magnetopolaron

effect for bound states in InP, beginning with the coupling of the 2*p*+ state with the 1*s*+LO phonon state. We further observe the magnetopolaron effect associated with the metastable state 210 . In addition we report (i) the re-emergence of the 210 impurity state transition beyond the LO phonon manifold, (ii) the possible coupling of an impurity transition with the 1*s*+2LO phonon state, and (iii) both low- and high-energy one-phonon transitions of impressive richness and detail.

Power optimization in thermionic devices, *T E Humphrey, M F O'Dwyer and H Linke*, J. Phys. D: Appl. Phys. **38**, 2051 (2005)

Conventional thermionic power generators and refrigerators utilise a barrier in the direction of transport to selectively transmit high-energy electrons, resulting in an energy spectrum of electrons that is not optimal for high efficiency or high power. Here, we derive the ideal energy spectrum for achieving maximum power in thermionic refrigerators and power generators. By using energy barriers that block or transmit electrons according to their total momentum rather than their momentum in the direction of transport, the power of thermionic devices can, in principle, be doubled and the electronic efficiency improved by 25%.

Quantum, cyclic, and particle-exchange heat engines, *T.E. Humphrey, H. Linke,* Physica E**29**, 390 (2005)

Differences between the thermodynamic behaviour of the three-level amplifier (a quantum heat engine based on a thermally pumped laser) and the classical Carnot cycle are usually attributed to the essentially quantum or discrete nature of the former. Here we provide examples of a number of classical and semi classical heat engines, such as thermionic, thermoelectric and photovoltaic devices, which all utilise the same thermodynamic mechanism for achieving reversibility as the three-level amplifier, namely isentropic (but non-isothermal) particle transfer between hot and cold reservoirs. This mechanism is distinct from the isothermal heat transfer required to achieve reversibility in cyclic engines such as the Carnot, Otto or Brayton cycles. We point out that some of the qualitative differences previously uncovered between the three-level amplifier and the Carnot cycle may be attributed to the fact that they are not the same 'type' of heat engine, rather than to the quantum nature of the three-level amplifier per se.

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First Principles for Development of High Temperature Superconducting Wires

Years Funded:	2002	2003	2004	2005	2006
	$222,295	$233,899	$217,899	$203,899	$209,899
Total Funding:	$1,087.891				
Project ID:	DP0211240				
Chief Investigator:	SX Dou, J Horvat				
Assoc. Investigator:	H Weber, E Collings, J Habermeier				
Postgrad Student:	S. Keshavarzi, M. Roussel				

Significant advances in research of high temperature superconductors (HTS) have been made in the past decade. However, the full commercialisation of HTS devices has not yet been achieved because the levels of electrical performance remain just below those required for technical and commercial success. In order to secure the future of HTS it will be essential to increase the critical current density, reduce the AC losses and lower the cost. The objective of the proposed cluster of projects is to provide new insights into fundamental HTS materials properties such as critical current density, flux pinning, flux dynamics and AC losses by focussing on the complex interplay between physics, fabrication and materials issues. The knowledge gained will make possible improvements in the development of HTS conductors.

Analysis, simulation, fabrication and characterisation of reliable, robust and scalable compact cooling elements based on semiconductor nanostructures

Funded:	2003	2004	2005
Amount Funded:	$75,000	$80,000	$40,000
Total Funding:	$195,000		
Project ID:	DP0343516		
Chief Investigator:	C. Zhang, R.A. Lewis		
Postgraduate students:	M. O'Dywer		

Project Summary: Modern electronic, microelectronic and optoelectronic devices generally work better when they are cooler. We aim to develop a semiconductor nanostructure cooling element which directly integrates into existing devices. The solid-state cooling element will be reliable, robust, scalable and operate in any orientation. The basis of operation is thermionic emission - electrons are the working fluid.

Our project combines (1) analysis and simulation, (2) fabrication of nanostructures and (3) experimental test-benching using optical and electrical methods. The outcome of this research has the potential to revolutionise cooling of modern electronic and photonic systems, from computer motherboards to mobile phones.

Fabrication, Charge and Spin Ordering, Magnetoresistance, and polaron effects in nano-size and single crystals of novel transition metal perovskite oxide

Funded:	2003	2004	2005
Amount Funded:	$90,000	$77,000	$78,000
Total Funding:	$245,000		
Project ID:	DP0345012		
Chief Investigator:	X.L. Wang, M. Ionescu, Z.X. Cheng		
Partner Investigator:	Dr.M James, Prof. R.S. Liu, Prof. W. Lang		
Postgraduate students:	M. Farhoudi, G. Peleckis		

The aim of the project is to synthesize a systematic series of novel colossal magnetoresistance manganese, cobalt and iron based transition metal perovskite oxides in the forms of nano-structures, nano-structured composites and single crystals using advanced nano-technology and crystal growth techniques. Extensive fundamental studies on magnetoresistance, spin and change ordering, and nano-scale behaviours will be carried out by neutron diffraction, synchrotron radiation, transport and magnetic measurements over a wide temperature range and magnetic fields. The outcomes of this project are likely to lead to a better understanding of the colossal magnetoresistance mechanisms, the discovery of fascinating new physical phenomena and suitable magnetoresistance materials for superior magnetic recording, sensing and switch devices.

Control of Nano-Structure for Enhancing the Performance of Magnesium Diboride Superconductor by Chemical Doping

Funded:	2004	2005	2006
Amount Funded:	$100,000	$100,000	$105,000
Total Funding:	$305,000		
Project ID:	DP0449629		
Chief Investigator:	S.X. Dou, M.J. Qin,		
Partner Investigator:	D.C. Larbalestier, R.L. Flukiger, L.F. Cohen		
Postgraduate students:	W.K. Yeoh, O. Shcherbakova, Y. Zhang		

Superconductor technology will play a significant role in a wide range of industry sectors and environments in the twenty first century. Widespread applications now depend significantly on cost-effective resolution of fundamental materials and fabrication issues. The aim of the proposed program is to bring together international experts from four leading groups to tailor the microstructure at nanoscale to improve flux pinning and the critical current density of the newly discovered magnesium diboride superconductors through readily available chemical doping. The expected outcome is the capability to produce a new generation of superconductors having high performance at low cost.

Hydrogen storage materials for energy conversion applications

Funded:	2004	2005	2006
Amount Funded:	$85,000	$85,000	$85,000
Total Funding:	$255,000		
Project ID:	DP0449660		
Chief Investigator:	H.K. Liu, Z.P. Guo		
Partner Investigator:	J. Lee, A. Zuettel, P.H. Notten		
APD:	Mrs ZP Guo		
Postgraduate students:	Z.G. Huang		

For a clean environment, the ideal synthetic fuel is hydrogen because it is lightweight, highly abundant and its oxidation product (water) is environmentally benign. However, the effective storage of hydrogen remains a scientific challenge. This project aims to develop innovative materials with high hydrogen storage capacity and long cycle life, including new composite hydrides, catalysed metal hydrides and various nanotubes. The expected outcome is the achievement of high reversible hydrogen storage capacity to meet all the demands

required for energy conversion applications, in particular, for hydrogen storage/fuel-cell vehicular applications.

Development of high-temperature superconducting coated conductors by pulsed-laser deposition technique for future long-length applications

Funded:	2004	2005	2006
Amount Funded:	$70,000	$70,000	$70,000
Total Funding:	$210,000		
Project ID:	DP0451267		
Chief Investigator:	A.V. Pan, M. Ionescu		
APD:	A.V. Pan		

The aim of the project is to develop a novel technology for manufacturing flexible coated conductors with the help of a pulsed laser deposition technique, in order to enhance the current-carrying ability of high-temperature superconducting coatings (including multi-layered coatings) for future long-length high power applications. To achieve desirable electromagnetic properties governed by the nano-structures of the coatings, a well-balanced combination of world-class "global" and "local" electromagnetic property measurements with advanced structural characterisations is suggested. It is expected that a controlled network of nano-scale pinning centres will allow the development of high performance coated conductors.

Non-linear dynamics in electronic systems and devices under intense terahertz radiation

Funded:	2004	2005	2006
Amount Funded:	$120,000	$140,000	$170,000
Total Funding:	$430,000		
Project ID:	DP0452713		
Chief Investigator:	C. Zhang R.A. Lewis X. Zhang R.E. Vickers		

Non-linear interactions allow for a detailed and intricate probing of materials. Sufficiently high-power light directed at a subject can yield spectroscopic data about multiple material parameters, providing a unique diagnostic tool for many applications. We propose to study the non-linear dynamic properties of electronic systems and devices under various external conditions. A thorough understanding of non-linear properties will accelerate development of new optoelectronic device in the terahertz frequency regime. Examples of these devices are oscillators and sensors.

Development of new technology for coated conductors able to carry "over-critical" current densities

Years Funded:	2005	2006	2007
	$125,000	$110,000	$100,000
Total Funding:	$335,000		
Project ID:	DP0557554		
Chief Investigator:	AV Pan, S Zhou, Y Genenko, TH Johansen		

The superconductivity phenomenon has extremely attractive feature, that superconductors can carry non-dissipative currents, enabling us to reduce energy consumption by up to 50%. The new advanced method suggested in this project might give a new, fresh and inexpensive boost to not only domestic superconducting industry, but also worldwide. The development of new high performance superconductor technology would significantly promote fundamental understanding and knowledge of the poorly investigated “long-range” magnetic interaction between magnetic and superconducting materials. The University of Wollongong would lead the world research community in this practically important and scientifically intriguing area.

Synthesis of nanowires and application as nanosensors for chemical and biological detections

Years Funded:	2005	2006	2007
	$80,000	$78,000	$80,000

Project ID: DP0559873
Total Funding: $238,000
Chief Investigator: G Wang, KK Konstantinov, J Ahn, XQ Yang, Z Xiao

This project is expected to bring significant scientific, economic and social benefits. We will develop a number of techniques for the controlled growth of nanowires and making functional nanoscale systems such as nanosensors. The nanosensors will have important applications in chemistry and biology. Some chemical species can be detected by nanosensors on molecular scale. The nanosensors could be used for early diagnostics of cancer disease, detection of viruses, and genomic DNA screening. The nanosensors could also provide a molecular tool for probing living cells without destroying them, through which we can track life within cells in real time

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:	XL Wang				

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.

ARC Research Fellowships

Development of new technology for coated conductors able to carry "over-critical" current densities
Australian Postdoctoral Fellow: S. Zhou

Development of high-temperature superconducting coated conductors by pulsed-laser deposition technique for future long-length applications
Australian Postdoctoral Fellow: A.V. Pan

Hydrogen storage materials for energy conversion applications
Australian Postdoctoral Fellow: Z. P. Dou

Lithium/Sulphur rechargeable battery for power applications
Australian Postdoctoral Fellow: J. Wang

Exploration for new materials for spintronics
QE-II Fellow: X. L. Wang

First Principles for Development of High Temperature Superconducting Wires
Australia Professorial Fellowship: S. X. Dou

Develop highly conductive nanocomposite electrodes for Li-battery
Australia Professorial Fellowship: H. K. Liu

Strategic Partnerships with Industry - (SPIRT) Scheme - Linkage Projects & Linkage APAI

Lithium/Sulphur rechargeable battery for power applications

Years funded:	2004	2005	2006
Amount funded:	$75,000	$75,000	$75,000
Total funding:	$225,000		
Project ID:	LP0453698		
Chief Investigator:	H.K. Liu, J. Wang, G. Wang		
APD Award(s):	J. Wang		
Industry Partner(s):	Guangzhou Delong Energy Technology		

The Lithium/Sulphur battery system is very promising for large-scale power applications as it has the highest energy density and lowest cost among various types of rechargeable batteries. However, the degradation of the capacity and the short cycle life of Li/S battery have been problematic for commercial development. The aim of this project is to study the mechanisms of capacity fading and to develop effective means such as the use of carbon nanotubes and nanosize composite absorbents to improve the cycle life of Li/S batteries. The expected outcomes are the development of sulphur-containing cathode materials and polymer electrolytes, enabling electric vehicles to be a technically competitive and environmentally superior transportation option.

Novel electric field induced coupling technique for liquid-phase heteroepitaxial growth of carbon thin films with diamond-like structure

Years funded:	2005	2006	2007	2008
Amount funded:	$12,000	$24,000	$24,000	$12,000
Total funding:	$72,000			
Project ID:	LP0561605			
Chief Investigator:	SX Dou, AV Pan			
APA(I) Award(s):	1			
Industry Partner(s):	Polarised Technology Pty Ltd			

The aim of the project is the growth of carbon thin films with a robust diamond-like structure for high performance electronic applications via the development of a new growth technique: Electric Field Induced Coupling (EFIC), which is based on liquid-phase layer-by-layer heteroepitaxial growth. The EFIC technique employing unique polarisation-induced growth will significantly enhance technological output compared to existing technologies by overcoming current difficulties with expensive and complicated production methods. Ambient temperatures and pressures employed by the technique will enable us to form diamond-based semiconductors at low cost with sufficient speed and the properties required for industrial production.

Large-scale rechargeable lithium battery for power storage and electric vehicle applications

Years funded:	2004	2005	2006
Amount funded:	$110,000	$110,000	$110,000
Total funding:	$330,000		
Project ID:	LP0453766		
Chief Investigator:	G. Wang, H.K Liu, K. Konstantinov, J. Ahn, B. Ammundsen		
APA(I) Award(s):	J. Yao		
Industry Partner(s):	Pacific Lithium New Zealand Limited, Sopo Battery Energy Co., Ltd		
Postgraduate student:	S. Needham		

This project aims to develop large-scale rechargeable lithium batteries for power storage and electric vehicles. In order to achieve this target, the related cathode materials, anode materials and electrolyte systems will be developed. The design of battery modules and assembly of prototype lithium ion batteries will be performed. The success of the research will encourage the production of electrode materials and

manufacture of rechargeable lithium batteries in Australia. The utilisation of advanced rechargeable lithium batteries in electric vehicles will provide sustainable energy for transportation and greatly reduce green-house emissions in Australian urban areas.

Enhancing the Understanding and Performance of Passivating TiO2 Coatings for Photovoltaic Devices

Years funded:	2004	2005	2006	2007
Amount funded:	$75,000	$127,500	$105,000	$52,500
Total funding:	$360,000			
Project ID:	LP0455328			
Chief Investigator:	BS Richards, M Ionescu			
Partner Investigators:	KR McIntosh, KM Provancha, R Swanson			
APA(I) Award(s):	1			
APDI :	BS Richards			
Industry Partner(s):	Keith McIntosh Consulting, Sierra Therm Production Furnaces, Inc. Sun Power Corporation			

Titanium dioxide (TiO2) has been widely used as an anti reflection coating in the silicon (Si) photovoltaics industry as it exhibits excellent optical properties and low deposition cost. However, recently manufacturers have been turning to alternatives such as hydrogenated silicon nitride coatings that exhibit greatly improved electronic properties, but cost 4 - 10 times more to deposit.

This project seeks to understand the fundamental limitations behind the poor surface passivation afforded by TiO2 to a Si wafer, and subsequently develop a passivating TiO2 coating that can reduce the cost of electricity generated by Si solar cells.

Development of Magnesium Diboride Superconductor Wires with High Upper Critical Field for MRI Applications

Years funded:	2005	2006	2007
Amount funded:	**$**169,612	$170,861	$174,831
Total funding:	$515,304		
Project ID:	LP0560280		
Chief Investigator:	SX Dou, MJ Qin, AV Pan, X Wang, EW Collings		
Partner Investigators:	KR McIntosh, KM Provancha, R Swanson		
APA(I) Award(s):	2		
Industry Partner(s):	Hyper Tech Research Inc Alphatech International Ltd		

The aim of the program is to demonstrate the superconducting magnesium diboride (MgB2) wires with improved upper critical field (Hc2,) appropriate for large-scale applications. The basic idea will be based on the two-gap superconductivity to add well distributed impurities which will act as scatterers, increasing resistivity, and thus Hc2. The core innovation of this proposal is based on the recent breakthrough in MgB2 that was made by the CIs through nano-SiC particle doping, which achieved a record high Hc2 in bulk form and enhancement of critical current density, Jc, in magnetic fields by an order of magnitude. The expected outcome is the development of superconducting MgB2 wires and coils with high Hc2 and Jc for MRI applications.

Linkage International Awards

Improvement of critical current density in MgB2 wires and tapes and Y-Ba-Cu-O coated conductors

Years funded:	2005
Amount funded:	$71,028
Total funding:	$71,028
Project ID:	LX0559656
Chief Investigator:	X Wang, SX Dou, J Yoo
Postgraduate students:	A.H. Li

The technology of superconducting wires and tapes has emerged as one of the most important basic engineering technologies, which can create technical innovation and improvement in the quality of life in the fields of electric power, energy, machinery, transportation and the environment in the 21st century. The aim of the proposed program is to develop magnesium diboride superconductor and YBCO coated conductors by using novel nano-precursor powders. Superconducting tapes doped with nano-sized powders are expected to show enhancement in flux pinning properties. The expected outcome is the capability to produce a new generation of superconductors having high performance at low cost.

Simulation and characterisation of opto-thermionic cooling devices

Years funded:	2003	2004	2005
Amount funded:	$15,700	$18,700	$18,700
Total funding:	$53,100		
Project ID:	LX0348004		
Chief Investigator:	Professor C. Zhang, A/Professor R.A. Lewis CI Prof KA Chao Lund University, Sweden		

The aim of the project is to study and develop a solid state cooling device by combining two mechanisms, thermionic emission and optical recombination. The first stage of the research is to develop theoretical models and numerical methods which will allow us to obtain an optimal condition of power and efficiency. Under this ARC LX grant, mutual visits for the Australian CIs and the international OI have been arranged. In October 2005, the international OI, K A Chao visited ISEM.

Photon induced nonlinear absorption and transport in semiconductor nanostructures

Years funded:	2005	2006	2007
Amount funded:	$8,000	$13,000	$5,000
Total funding:	$26,000		
Project ID:	LX0559621		
Chief Investigator:	Professor C. Zhang CI Prof JC Cao Chinese Academy of Sciences, China		

Photon induced transport in electronic systems is of great importance in fundamental science and in the development of new optoelectronics devices. In this project we aim to study the microwave radiation induced dc transport and nonlinear absorption in high mobility systems. The result will shed light on newly discovered zero-resistance state in semiconductor nanostructures. The expected outcome is an improved understanding on the mechanism of reducing dc resistance in low-dimensional electronic systems.

Molecular dynamic simulation and experimental study on the mechanisms of high critical current density in superconductors

Years funded:	2005	2006	2007
Amount funded:	$11,300	$11,300	$11,300

Total funding:	$33,900
Project ID:	LX0560106
Chief Investigator:	Dr M Qin
	Prof. S. Ding, Nanjing University, China

The aim of this project is to establish collaboration between the Institute for Superconducting and Electronic Materials (ISEM) and the team at Nanjing University to study the mechanisms of high critical current density (or flux pinning) in superconductors.

Molecular dynamic simulation combined with experimental techniques, such as transport and magnetic measurements will be used. The results of this work will expand our understanding of the pinning mechanisms of high temperature superconductors and MgB2 superconductors, with the hope of further enhancing the current carrying capacity, and therefore promoting the practical applications of superconductors.

Magneto-optical imaging of super-current flow in superconducting tapes and wires

Years funded:	2004	2005	2006	
Amount funded:	$14,140	$10,960	$11,160	
Total funding:	$36,260			
Project ID:	LX0453582			
Chief Investigator:	1	CI	Prof SX Dou	University of Wollongong
	2	CI	Dr AV Pan	University of Wollongong
	3	OI	Prof TH Johansen	University of Oslo
Collaborative Countries:	Norway			

This project is aimed at establishing the connections between local and global superconducting current-carrying abilities in magnesium diboride and high temperature superconducting tapes and wires. Local high-resolution magneto-optical imaging combined with transport current techniques will be employed. Super-current stream-lines and critical current density distributions will be quantitatively obtained from local magnetic flux behaviour. Pinpointing the connections is expected not only to promote production technology, but also to elucidate factors influencing the current-carrying ability in the tapes and wires.

Sustainable Energy Research and Development Fund
New South Wales State Government & CSIRO Flagship

Nanofabrication facilities for processing of novel multilayer materials

Years funded:	2004	2005	2006	2007
Amount funded:	$29,000	$20,000	$85,000	$16,000
Total funding:	$150,000			
Project manager:	Prof C Zhang			

To fabricate and measure power generation and cooling effects in a new, highly efficient, type of thermionic device which incorporates energy filters for electronic transport in the form of arrays of quantum dots. The proposed device will incorporate the best features of both multilayer and vacuum thermionic technologies by allowing contact between the hot and cold areas of the device only via arrays of quantum dots. Individual dots in the array will be separated from each other by vacuum or suitably insulating material

Australian Institute of Nuclear Science and Engineering Award

Oxygen contamination and element depth profile in MgB2 thin films
Amount funded: $3,139
Chief Investigator: H K Liu

Structure and interface control in mono- and multi-layered high temperature superconducting films
Amount funded: $3,139
Chief Investigator: A V Pan

Understanding the role of hydrogen in passivating amorphous silicon nitride dielectric coatings
Amount funded: $3,139
Chief Investigator: B Richards

Study of critical current density, superconductivity, and crystal structure of bulk MgB2 prepared by the in-situ reaction technique
Amount funded: $6,010
Chief Investigator: S Soltanian

Australian Academy of Sciences

Scientific Research Grant to Europe

Amount funded:	**Chief Investigator:**
$11,000	K. Konstantinov

URC Small Grants & ARC Near Miss Grants

Nonequilibrium superconductivity and quasiparticle dynamics of superconducting materials under terahertz radiation (DP near miss)

Amount funded:	**Chief Investigator:**
$10,000	M. Qin

Development of Giant Magnetocaloric Materials for Refrigeration Applications (DP near miss)

Amount funded:	**Chief Investigator:**
$10,000	R. Zeng, T. M. Silver, S. Y. Ding

Novel ferroelectric magnetic materials for multi-functional applications

Amount funded:	**Chief Investigator:**
$14,500	X. L. Wang

Stronger pinning and larger currents for the second generation of superconducting wires based on thin film technology

Amount funded:	**Chief Investigator:**
$10,000	A. V. Pan

Preparation and characterisation of functional semiconductor nanowires

Amount funded:	**Chief Investigator:**
$7,500	G X Wang

Optimised LiFePO4 Using Conducting Polymers for Rechargeable Lithium-ion Batteries

Amount funded:	**Chief Investigator:**
$8,500	J. Wang and J. Chen

Optical Readout Of Silicon: Phosphorous Electronic States For Quantum Computation

Amount funded:	**Chief Investigator:**
$14,500	R. A. Lewis

University of Wollongong

University Research Council, ISEM Performance Indicator & Management

Year funded:	2005	**Amount funded:**	$125,000

Conferences

12th International Conference on Modulated Semiconductors, 10-15 July 2005, Albuquerque, NM, USA

Exchange-enhanced spin-splitting in a two-dimensional electron gas in the presence of the Rashba spin–orbit interaction, *C.H. Yang, W. Xu, Z. Zeng, C.S. Tang and C. Zhang*

We present a theoretical study on how many-body effects can affect the spin-splitting of a two-dimensional electron gas in the presence of the Rashba spin–orbit interaction. The standard Hartree–Fock approximation and Green's function approach are employed to calculate the energy spectrum and density of states of a spin-split two-dimensional electron gas (2DEG). We find that the presence of the exchange interaction can enhance significantly the spin-splitting of a 2DEG on top of the Rashba effect. The physical reasons behind this important phenomenon are discussed.

16th International Conference on Electronic Properties of Two-Dimensional Systems, 10-15 July 2005, Albuquerque, NM, USA

Frequency-dependent Hall effect in spintronic systems under zero magnetic field, *C. Zhang, Z. S. Ma, and W. Xu*

It is shown that in an electronic system with finite Rashba coupling and in the absence of external magnetic field, the Hall resistivity (ρ_{xy}) is finite at both zero and finite frequencies. This Hall resistivity is determined by the reactive part (real part) of the inverse dielectric functions. This allows us to probe the real part of the dielectric function in a spintronic system by using a transport measurement.

Fast-electron optical spectrum of a two-dimensional electron gas in the presence of the Rashba effect, *W. Xu, Z. Zeng, F. Lu and C. Zhang*

We examine how the Rashba spin-orbit interaction (SOI) affects the fast-electron optical spectrum of a two-dimensional electron gas (2DEG). It is found that for a spin-split 2DEG, the spectrum of optical absorption is mainly induced by plasmon excitation via inter-SO electronic transition. From the width and position of the spectrum, the Rashba spin-splitting can be identified optically and, therefore, important spintronic properties can be measured though optical experiments

3rd International Conference on Materials for Advanced Technology, 3-8 July 2005, Singapore

Far Infrared Spectra of $La_{1-x}Ca_xMn_{0.9}Li_{0.1}O_3$, F. *Gao, R. A. Lewis, X. L. Wang, S. X. Dou*

This work is a study on phonon modes of polycrystalline $La_{1-x}Ca_xMn_{1-y}Li_yO_3$(x = 0.1 - 0.5) by far infrared (FIR) spectroscopy. Samples were prepared by a conventional solid state reaction method. Lithium is a volatile element which can cause changes in the FIR spectra of compared to the spectra of $La_{1-x}Ca_xMn_{0.9}Li_{0.1}O_3$. The far infrared spectra show that the external mode [La(Ca)] - [Mn(Li)O_3], the O - Mn(Li) - O bending mode and Mn(Li) - O stretching mode behave similarly and increase in energy as the Ca concentration increases. The Li^+ ion is lighter than the Mn^{3+} ion and its ionic radius is slightly larger than that of the Mn^{3+} ion. Thus Li doping introduces unit cells that are even smaller due the Mn^{4+} ions radius being smaller than Mn^{3+}. This will lead to new lattice modes. Also the high ionicity of Mn^{4+} leads to a stronger inter-ion electrostatic interaction. As a result the frequencies of lattice vibrations increase. Some

evidence of Li incorporation in the crystal lattice is useful, and Li ion doping has now been detected by our FIR spectroscopic technique. These phenomena are all observed in FIR transmission measurements

IEEE International Magnetics Conference, 4-8 April 2005, Nagoya, Japan

Infrared-active phonons of perovskite $HoMn_{1-x}Co_xO_3$(x=0--0.8), *F. Gao, X. L. Wang, M. M. Farhoudi, R. A. Lewis*

Polycrystalline perovskites compounds $HoMn_{1-x}Co_xO_3$ (x= 0-0.8) have been prepared by conventional solid state reaction. Here we used Far-infrared (FIR) spectroscopy to study infrared active phonon modes and present a comparative analysis of infrared transmission spectra of polycrystalline $HoMn_{1-x}Co_xO_3$ (x= 0-0.8). The data indicated that phonon modes significantly changed with increase of cobalt doping level. Four main bands were assigned as external, torsional, bending and stretching bands. The external vibration energy remains the same at ω_1~190 cm^{-1} for Co doping $x \leq 0.5$ and shift to a higher energy for x >0.5. Torsional and bending bands exhibit splitting. Stretching bend is at 600 cm^{-1} for all samples, but the band width is reduced as Co doping increased. The transmission spectrum of $HoMn_{4/5}Co_{1/5}O_3$ was analysed to the spectrum of optical density. The minimum number of oscillators to obtain a reliable fit is 5 by using a sum of non interacting harmonic oscillators.

Structure, spin glass, and spin state in perovskite GdCo1-xMnxO3, *M.M Farhoudi, X. L. Wang,*

Perovskite GdCo/sub 1-x/Mn/sub x/O/sub 3/ (x=0.2,0.3,0.4,0.5) compounds have been prepared by solid-state reaction. Structures were characterised using X-ray diffraction and Rietveld Refinement method. The compounds crystallised in orthorhombic with Plmn space group. Crystal lattices decreased with the increase of Mn doping level. DC magnetisation and ac susceptibility were studied over a wide temperature range and different frequencies. A typical spin glass state was observed in all samples around the same temperature of 122 K where the compounds turned from paramagnetic to ferromagnetic states. For x<0.5, secondary transitions were observed both in dc and ac measurement which were independent of frequency but depended on doping level. The valences of Co or Mn with possible spin states were estimated.

Absence of ferromagnetism and strong spin-orbital coupling in polycrystalline in and Co codoped $Zn_{1-x}In_xCo_{0.075}In_xO$ oxide, *G. Peleckis, X. L. Wang, S. X. Dou*

Polycrystalline samples of In and Co codoped ZnO ($Zn_{1-x}In_xCo_{0.075}O$; 0.010<x<0.020) oxide were prepared by solid-state synthesis technique. Phase purity and structure refinement done by means of the Rietveld analysis technique shows that both Co and In substitute properly into Zn positions. In doping, increased bulk conductivity of the samples at room temperature indicates an increase of charge carrier concentration. All samples showed paramagnetic behaviour following Curie-Weiss law at close to room temperatures, with short range antiferromagnetic interaction with $\Theta \approx -200$ K. Effective magnetic moment (μ_{eff}) calculations showed a strong orbital contribution to the value of μ_{eff}, increasing with an increase of In content (x).

Co valence by K-edge X-ray absorption spectroscopy, magnetic properties, and structure of polycrystalline bulk $Zn_{1-x}Co_xO$, *G. Peleckis, X. L. Wang, R. S. Liu, S. X. Dou*

We report on magnetic properties and a Co K-edge X-ray absorption spectroscopy (XAS) study of polycrystalline bulk $Zn_{1-x}Co_xO$ (x=0.10,0.15,0.17) samples. All samples show paramagnetic behaviour and no ferromagnetism was observed. XAS results showed that for all samples the valence of Co is 2+. Spin state assessment derived from Currie-Weiss fitting indicated a possible spin state transition from Co^{2+} high spin to Co^{2+} low spin. Calculated μ_{eff} values for samples with x=0.10 and 0.15 indicated an orbital contribution to the effective magnetic moment of the Co ion.

Joint 30th International Conference on Infrared and Millimeter Waves and 13th International Conference on Terahertz Electronics, 19-23 September 2005, Virginia, USA

Terahertz Emission from (100) p-InA , *M. L. Smith, R. Mendis, R. E. M. Vickers and R. A. Lewis*

Terahertz emission from (100) p-type InAs illuminated by ultra fast near-infrared pulses is investigated. A two-fold rotational symmetry was observed when rotated about the surface normal. A quadratic relationship was found for the emission dependence on optical pump power. These suggest the presence of photo-carrier transport and optical rectification mechanisms. The InAs emission was found to exceed that of a blackbody radiator for frequencies below 1 THz for nominal input power levels. The generated power was found to be roughly two orders of magnitude greater than a 1mm ZnTe emitter.

European Conference on Applied Superconductivity (EUCAS-05), 11-15 September 2005, Vienna, Austria

Structure, pinning and current in $ReBa_2Cu_3O_7$ films and multilayers, *A. V. Pan, G. Alvarez, S. Pysarenko, M. Roussel, and S. X. Dou*

High quality films and multilayers of $ReBa_2Cu_3O_7$ superconductors, where Re is rare earth elements, have been prepared by pulsed laser deposition. Pinning characteristics of the structures obtained have been analysed and attributed to growth conditions and corresponding structural peculiarities. Critical current density in the samples was obtained globally and locally. Its variations and differences in films and multilayers are discussed in terms of defects produced by the growth of the layers.

10th International Superconductive Electronics Conference, 5-9 September 2005, NH Leeuwenhorst, Noordwijkerhout, The Netherlands,

Superconducting Properties and Surface Morphology of $YBa_2Cu_3O_7$ Films versus (Re)$Ba_2Cu_3O_7$ Multi-layers, *A. V. Pan, S. Pysarenko, G. Alvarez, and S. X. Dou*

Much smoother surfaces and significantly improved superconducting properties of relatively thick $YBa_2Cu_3O_7$ (YBCO) films have been achieved by introducing a multilayered structure with alternating main YBCO and additional NdBCO layers. The surface of thick (1 μm) multilayers has significantly improved structure compared to YBCO films and its roughness is much less than even in thin (50 nm) YBCO films. Critical current density (Jc) have been drastically increased in 1 μm multilayered structures compared to YBCO films over entire temperature and applied magnetic filed range. Moreover, the Jc values measured in thick multilayers are even larger than in YBCO films with "optimal" (100 to 400 nm) thickness. The J_c improvement have been analysed and attributed to growth conditions and corresponding structural peculiarities.

24th International Conference on Thermoelectrics, 19-23 June 2005 Clemson, South Carolina, USA

The effect of the electron energy spectrum on electronic efficiency and power in thermionic and thermoelectric devices, *M. F. O'Dwyer, T. E. Humphrey, R. A. Lewis and C. Zhang*

We show that the details of the energy spectrum of transmitted electrons in thermionic and thermoelectric devices have a significant impact on their performance. We distinguish between traditional thermionic devices where electron momentum is filtered in the direction of transport only and a second type, in which the electron filtering occurs according to total electron momentum. Our main result is that the electronic efficiency of a device is not only improved by reducing the width of the transmission filter, but also strongly

depends on whether the transmission probability rises sharply from zero to full transmission. Finally, we comment on the implications of the effect the shape of the electron energy spectrum has on the efficiency of thermoelectric devices and suggest an experimental measure for providing insight into the nature of the electron energy spectrum.

A further comparison of solid-state thermionic and thermoelectric refrigeration, *T. E. Humphrey1, M. F. O'Dwyer and A. Shakouri*

We show that the expressions for current and heat current calculated via (the non-linearized) ballistic and diffusive transport formalisms reduce to the same form for solid-state devices one electron mean free path in length. The materials parameters for thermionic and thermoelectric devices are also shown to be equal, rather than differing by a multiplicative constant. We derive a simple transport equation that includes both ballistic and diffusive contributions to the current, and, as an example, use this to calculate the maximum temperature difference obtainable for a piece of Bi_2Te_3 as a function of its length, from less than an electron mean-free path to much greater than a mean-free path. Finally we briefly discuss similarities and differences between thermionic and thermoelectric devices in the regime where device length is of the order of a mean-free path length.

SPIE Conference on Microelectronics, MEMS, and Nanotechnology, 11 - 14 December 2005, Brisbane, Australia

The Effect of Barrier Shape on Thermionic Refrigerator Performance, *M. F. O'Dwyer, T. E. Humphreyb, R. A. Lewis, C. Zhang and K. A. Chao*

We consider the effect that the barrier shape has on the electron energy spectrum and lattice thermal conductivity, and together the COP of thermionic refrigerators. Whilst it is shown that wide barriers are also desirable to enhance the electron energy spectrum, the primary motivation to increase barrier width to the maximum allowable value with ballistic transport is to reduce thermal conductivity. It is shown that the barriers which produce the highest electronic COP do not necessarily give the highest COP when thermal conductivity is considered if electronic heat current is reduced. While mean free path length multi barrier geometries may offer reduced thermal conductivity due to the possibility of interface scattering and phonon mini band formation, this effect needs to be significant to achieve COP comparable with a single barrier device. Finally, we show that maximum refrigerator COP is achieved by transmitting electrons over a tuned energy range only, a filter which may be approximated by the transmission probability associated with a Gaussian modulated superlattice.

Conventional and total momentum filtered thermionic devices, *M. F. O'Dwyer, T. E. Humphrey, R. A. Lewis and C. Zhang*

Conventional solid-state and vacuum thermionic devices restrict the flow of electrons between the hot and cold reservoirs according to the magnitude of their momentum in the direction of transport only. Recently it has been suggested that devices may be developed where the filtering of transmitted electrons occurs according to their total momentum. We compare the performance differences associated with these two different methods of electron momentum filtering in single barrier and resonant tunnelling thermionic refrigeration devices. It is shown that total momentum filtered single barrier refrigerators always out-perform conventional single barrier refrigerators due to their larger heat current which is particularly important when the thermal conductivity of the system is significant. We show that whilst conventionally filtered resonant tunnelling thermionic refrigerators are out-performed by total momentum resonant tunnelling thermionic refrigerators in general conditions, their performance is superior at high temperatures or when the transmission energy is very close to the Fermi energy.

23rd International Conference on Defects in Semiconductors, 24-29 July 2005, Awaji Island, Japan

Magnetospectroscopy to 30 T of donor states in InP, *R.A. Lewis,_, P.E. Simmonds, Y.-J. Wang*

Far-infrared absorption spectroscopy in the energy range 100–400 cm_1 is reported for donors in indium phosphide at 4.2K in magnetic fields of up to 30 T. Transitions are observed from the bound-electron ground state to both stable and metastable excited states in good agreement with the effective-mass theory. At the highest magnetic fields employed, corresponding to 2ogo3, several absorption features are observed just above the TO-phonon energy, _5 effective Rydberg. These are attributed to the magnetopolaron interaction and cyclotron resonance.

16th National Congress of Australian Institute of Physics, 31 January-4 February 2005, Canberra, ACT

Magnetospectroscopy to 18 T of Phosphorous Donor in Silicon, *R.A. Lewis, R.E.M. Vickers, and Y.-J. Wang.*

We report the far-infrared absorption magnetospectroscopy of P donor in Si to higher magnetic fields than those employed previously. Absorption spectroscopy provides additional information to that provided by PTIS for P donor in Si. Anti-crossings between various states have been observed.

Zeeman Spectra of Boron in Germanium at High Fields, *R. E. M. Vickers, R. A. Lewis, P. Fisher, Y.-J. Wang,*

Zeeman spectra of boron in germanium have been examined for B||<110> in the Faraday configuration with fields up to 18T. Previous studies [1] have been confined to 0–7T, for the Voigt arrangement with linearly polarised radiation. All spectral lines yield detailed Zeeman patterns; that of the G line will be presented for the range 0–18T along with a comparison with theory from 1–10T.

A new THz facility for condensed matter physics, *R. A. Lewis, R. E. M. Vickers and M. L. Smith*

This paper describes a new THz facility for condensed matter physics that complements the existing infrastructure at the University of Wollongong (UoW). The THz regime is of immense importance in condensed matter physics as many energies of interest fall in this region—phonon energies, cyclotron energies in laboratory magnetic fields, energies of shallow impurities in semiconductors, bound levels in heterostructures, to name a few.

Spectroscopy of acceptor states in ZnSe, *R. A. Lewis, R. E. M. Vickers, H. Nakata and Y.-J. Wang*

We report the infrared absorption spectrum of nominally undoped bulk crystalline ZnSe prepared by the solid growth method, and expected to contain Li as the chief unintentional impurity. Our data resolves features more clearly than does previous work. On the basis of the data and analysis presented we discuss earlier interpretations of the myriad absorption features and suggest a new explanation: that the origin of the complex structure in the absorption spectrum of ZnSe is the presence of more than one acceptor.

Invited Speaker Presentations / Seminars

MRS Spring meeting, 25th to 29th April 2006, San Francisco, LA USA

S.X. Dou, - $J_c(H)$ *and* H_{c2} *of* MgB_2 *Conductors (Invited talk)*

MEM05, 18th to 20th July, Kyoto Japan,
S.X. Dou - *Light, Strong and High Performance* MgB_2 *Conductor (invited talk)*

Pac Rim 6th, 11-16 Sept 2005 Ritz Carlton, Maui, USA

S.X. Dou, - *High Performance Nano SiC Doped* MgB_2 *Conductors (Invited talk)*

ICMC, 28th Aug to 2nd Sept 2005, Keystone, Colorado, USA Kyoto Japan,
S.X. Dou - *Nano SiC and CNT doping to* MgB_2

Asian Applied Superconductivity Conference, 14th to 16th Nov 2005 Puhan, Korea

S.X. Dou - *Nano-scale doping to enhance critical current density in superconductors (invited talk)*

Tienjin University, Tienjin, China, 9th Nov 2005,

S.X. Dou - *Recent development in energy materials at ISEM*

Nankai University, Tienjin, China, 10th Nov 2005,

S.X. Dou - *Recent development in energy materials at ISEM*

Shanghai University, China, 2nd Nov 2005

S. X. Dou - *Superconducting and electronic materials*

Technical University of Vienna, Austria, 30th May, 2005

R. A. Lewis - *Terahertz technology and material properties*

ENEA Institute, Frascati, Italy, 1st June 2005

R. A. Lewis, - *An investigation of novel lithium iron phosphate cathode materials*

Lund University, Sweden, 9th June 2005

R. A. Lewis – *Advanced Materials in THz Science and Technology*

Korea Electrotechnology Research Institute, Changwon, Korea, 22nd March, 2005

G. X. Wang - *Development of large-scale Lithium-ion batteries for electric vehicle application*

Shanghai JiaoTong University, Shanghai, P.R.C. 26th March 2005

G.X. Wang, - *An investigation of novel lithium iron phosphate cathode materials*

Shanghai Institute of Microsystems and Information Technology, Chinese Academy of Science, 4th July 2005

C. Zhang – *Thermionic emission in semiconductor nanostructures*

Xi'an University of Science and Technology, China, 8th July 2005

C. Zhang – *Terahertz spintronics*

Seminars by Visiting Scientists

Date	Name	Institute	*Title*
7th Jan. 05	Prof Volodymyr M Pan	G V Kurdyumov's Institute for Metal Physics National Academy of Sciences of Ukraine	Microwave Properties in Perfect High-Tc Superconducting YBCO Films and Development of Front End Device for Base Station of Wireless Telecommunications
13th Jan 05	Prof Volodymyr M Pan	G V Kurdyumov's Institute for Metal Physics, National Academy of Sciences of Ukraine	Two-Peak Temperature Dependence of Microwave Surface Impedance in Perfect Single-Crystal YBCO Thin Films: Role of Pairing Symmetry and Defect Structure
14th Jan 05	Prof Zi-Feng Ma	Department of Chemical Engineering, Shanghai Jiao Tong University, China	Prospect and Application of PEM Cell in China
4th Feb 05	Professor E.W. Colling	Laboratories for Applied Superconductivity and Magnetism, Dept. of Materials Science and Engineering The Ohio State University Columbus, OH, USA	Advances in MgB_2 strands and possibilities for applications
6th April 05	Dr. Nagarajan Valanoor	School of Materials Science and Engineering, University of NSW	Nanoscale Phenomena in Epitaxial Ferroelectric Thin films
27th May 05	Prof Richard B Kaner	University of California, Los Angeles (UCLA)/ Intelligent Polymer Research Inst. (UoW)	It's a Material World
10th June 05	Prof Zi-Feng Ma	Department of Chemical Engineering Shanghai Jiao Tong University, China	Electrocatalyst design and characterisation for polymer Electrolyte Membrane Fuel cell
13th Sept 05	Dr W Xu	Research School of Physical Science and Engineering, Australian National University	Transport coefficients of a 2DEG in the presence of spin-orbit interaction
6th Sept 05	Professor Hiroyasu Nakata	School of Science, Osaka Kyoiku University	Infrared photoconductivity of Ge:Te
19th Oct 05	Prof K A Chao	Department of Physics, Lund University	Temperature related problems in nanoscale systems
28th Nov 05	Dr Nikolai Lobanov	Nuclear Physics Department Research School of Physical Sciences and Engineering ANU	RF Superconductivity for Particle Accelerators 2005"
9th Dec 05	Dr. Charles Dewhurst	Institut Laue-Langevin, France	Small Angle Neutron Scattering (SANS) studies of the vortex lattice in type II superconductors

Equipment and Facilities

ISEM facilities contain 9 laboratories with a floor space of approx 420m^2 comprising modern facilities for processing and characterisation of HTS and energy storage materials; materials processing and a full range of materials characterisation.

The majority of these facilities were founded through six ARC RIEF programs and the Metal Manufactures Ltd Consortium program over the past six years.

The following institutions and Chief Investigators have been involved with the ARC RIEF proposals:

Australian National University	Dr M. Das
Australian Nuclear Science & Technology Organisation	Dr E.R. Vance
CSIRO	Dr N Saviddes, Dr K Müller
Curtin University	Prof D.Y. Li and Dr I. Low
James Cook University	Prof J Mazierska
Macquarie University	A/Prof E Goldys
Monash University	Dr YB Cheng, Dr. R. Krishanmurthy
University of Melbourne	A/Prof DN Jamieson
University of NSW	Prof M Skyllas-Kazacos, Dr R. Ramer
University of Queensland	Prof. M.G. Lu, Prof D.R. Mackinnon
University of Sydney	A/Prof S Ringer, Dr V Keast
University of Technology, Sydney	Prof J. Smith
Curtin University	A/Prof J. Low
University of West Sydney	Prof. M. Wilson

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, 10-30μm droplets, 0.1-1 litre/hour
- Bull Block, 22cm diameter
- Rolling mill, 2 x 60mm flat & square rollers, 5cms
- Rolling mill, 2 x 55mm supported rollers, 5cm/s
- Swagging machine, 15-1mm diameter
- Hydraulic press, 10t-100t
- More than 30 various furnaces
- Controlled atmosphere glove boxes
-

Thin Film Deposition and Structuring Facilities

- Excimer laser, ComPex301, 9W, 10Hz, 248nm
- Thin Films Pulsed-Laser Deposition (PLD) Chamber, 18" dia. With high vacuum system
- Ultra High Vacuum (UHV) PLD chamber equipped with ISD and IBAD (to be completed in 2005).
- 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
- XRD for Single Crystals
- TEM, J2000FX1, with EDS
- Gas absorption analyser Nova 1000 for BET and pore size analyses
- XRD, M18XHFCu with HT 2000°C camera
- 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; XRD Texture, PW1078, 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
- Horizontal field superconducting Magnet, 0-8T, 5-300K
- 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
- Electromagnet, HSV-4H1, 2T, 100mm pole diameter
- 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
- Thermal conductivity measurement
- Function Generator, DSC340; Digital Oscilloscope, TDS320
- Digital Teslameter, DTM-132, with Hall Probe; Fluxmeter, 916
- 2 x He Recovery System, including liquefier – 40 litres/day
- 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 L He storage, 30 l L He storage, 60 l L N storage, 50 l L N storage, 2x30 l L N storage, 25 l L N storage, A system for recovering and compressing He gas is in place
- Leak detector Vacuum system

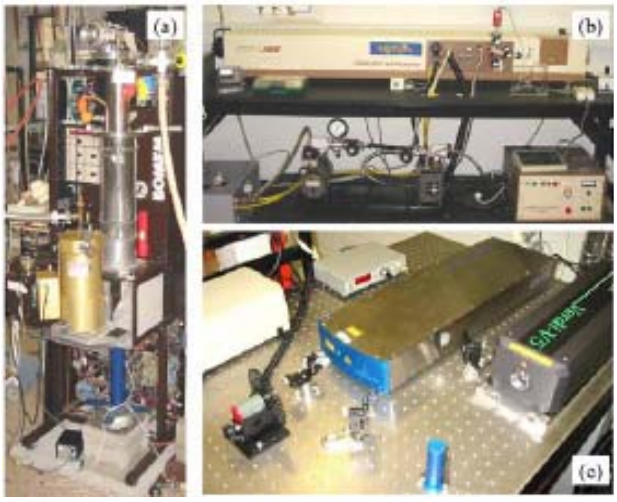
Electro-Chemical Property Characterisation

- Cyclic Voltammograph, BAS CV-27
- Impedance Analyser, M6310
- Temperature Controlled Water Bath, F10-MF
- Four Channels Data Collection System, MacLab/4e

Electro-Chemical Property Characterisation (continued)

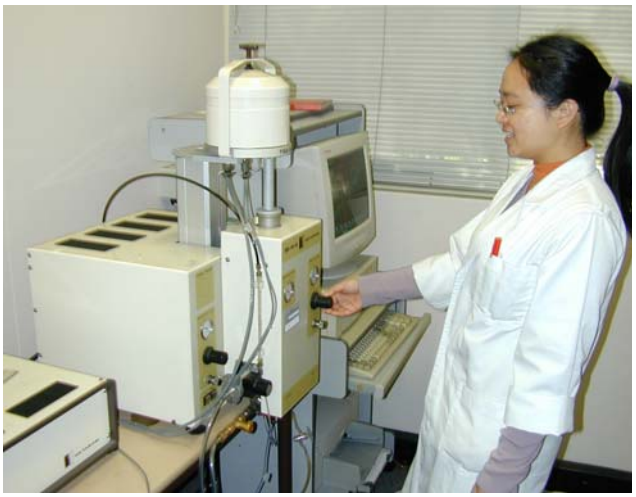
- ICP-OES, Vista MPX simultaneous axial spectrometer, 167-785nm range 0.009nm resolution 200nm
- Scanning Potentiostat, M326; Potentiostat, M363
- Power Supply, DCS 20-50, 0-20V, 0-50A
- Eight Channels Data Collection System, MacLab/8
- Controlled Atmosphere System (Glove Box), OP7
- Amplifiers, PAR 124A Lock-in, 2xPAR 5209 Lock-in, Stanford Research SR510
- CHI 660B Electrochemical Workstation
- Arbin MSTAT8000 Electrochemical Workstation
- Automatic PCT Measuring System

Ultra high vacuum (UHV) multi-purpose pulsed laser deposition (PLD) chamber with an incorporated ion gun for ion-beam assisted deposition (IBAD) and a possibility to carry out inclined substrate deposition (ISD) process. It is also equipped with a multi-target holder and large rotating substrate/sample heater/holder. The control instrument rack for automated control of the PLD chamber is situated next to it.



Terahertz facility

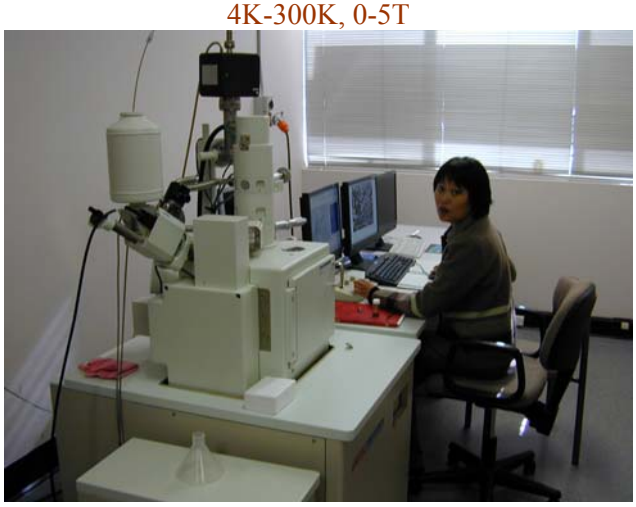
ICP-OES, Vista Simultaneous
Axial Spectrometer



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 Creating Oxygen and
Moisture free Environment

Refereed Publications

Book Chapters

1. **M J Qin and S X Dou**, "Superconductors, High Tc", (2005), in Bassani F, Liedl G L, Wyder P (eds) *Encyclopaedia of Condensed Matter Physics*, pp 33313-1 to 33313-4 Elsevier Academic Press, UK
2. **S X Dou, A V Pan, M J Qin, T Silver,** "Critical Current Density in Superconducting MgB_2", in Narlikar A V (eds), *Frontiers in Superconducting Materials*, pp1011-1048, Springer, US, (2005)
3. **D Milliken, T Silver, S X Dou, "**Irradiation of HTS for enhancement of critical current," in Narlikar A V (eds), *Frontiers in Superconducting Materials*, , pp554-588, Springer, US, (2005)

Journal Articles

4. **S X Dou, S Soltanian, Y Zhao, E Getin, Z Chen, O Shcherbakova, J Horvat, "**The effect of nanoscale Fe doping on the superconducting properties of MgB_2" Superconductor Science and Technology, Vol 18(5), (2005), pp710-715
5. **S X Dou, S Soltanian, W K Yeoh, Y Zhang,** "Effect of Nano-Particle Doping on the Upper Critical Field and Flux Pinning in MgB_2," IEEE Transactions on Applied Superconductivity, Vol 15 No 2, 3219-3222 (2005)
6. **F Gao, X L Wang, M M Farhoudi, R A Lewis**, "Infrared-Active Phonons of Perovskite $HoMn_{1-x}Co_xO_3$(x=0-0.8)", IEEE Transactions on Magnetics, Vol 41 No 10, pp2763-2765, (2005)
7. **Z P Guo, Z W Zhao, H K Liu, S X Dou,** "Electrochemical lithiation and de-lithiation of MWNT-Sn/SnNi nanocomposites" Carbon 43, (2005) 1392-1399
8. **Z P Guo, E Milin, J Z Wang, J Chen and H K Liu**, "Silicon/Disordered Carbon Nanocomposites for Lithium-Ion Battery Anodes", Journal of The Electrochemical Society, Vol 152 No 11, pp2211-2216, (2005)
9. **Z P Guo, H Liu, S Bewlay, H K Liu, S X Dou**, "Fine-Particle Carbon-enriched $Li_{0.98}Mg_{0.02}FePO_4$ Synthesised by A Novel Modified Solid-State Reaction", Synthetic Metals, Vol 153(1-3), pp113-116, (2005)
10. **Z P Guo, Z W Zhao, H K Liu, S X Dou**, "Lithium insertion in Si-TiC nanocomposite materials produced by high-energy mechanical milling", Journal of Power Sources, Vol 146(1-2), pp190-194, (2005)
11. **Z P Guo, J Z Wang, H K Liu, S X Dou**, "Study of Silicon/polypyrrole composite as anode materials for Li-ion batteries", Journal of Power Sources, Vol 146(1-2), pp448-451, (2005)
12. **T E Humphrey, H Linke,** "Reversible Thermoelectric nanomaterials" Physical Review Letters, 94, pp 096601-1 to 096601-4, (2005)
13. **T E Humphrey, M F O'Dwyer, C Zhang, R A Lewis, "**Solid-state thermionics and thermoelectrics in the ballistic transport regime", Journal of Applied Physics 98, pp 026108-1 to 026108-3 (2005)
14. **J Horvat, S Soltanian, W K Yeoh,** "The relevance of the self-field for the 'peak effect' in the transport $J_c(H)$ of iron-sheathed MgB_2 wires" Superconductor Science and Technology 18, 682-688, (2005)
15. **J Horvat, W K Yeoh, L M Miller**, "Interaction between superconductor and ferromagnetic domains in iron sheath: Peak effect in MgB_2/Fe wires, Applied Physics Letters, Vol 87 No 10, pp 102503-1 to 102503-3, (2005)
16. **M James, K S Wallwork, R L Withers, D J Goossens, K F Wilson, J Horvat, X L Wang, M Colella,** "Structure and magnetism in the oxygen-deficient perovskites $Ce_{1-x}Sr_xCoO_{3-8}$ (x>0.90), Materials Research Bulletin 40 (2005) 1415-1431.
17. **A H Li, H K Liu, M Ionescu, X L Wang, S X Dou,** "Improvement of critical current density and thermally assisted individual vortex depinning in pulsed-laser-deposited $YBa_2Cu_3O_{7-}$ thin films on $SrTiO_3$ (100) substrate with surface modification by Ag nanodots" Journal of Applied Physics Vol 97(10), pp1-3 (2005).
18. **A H Li, M Ionescu, H K Liu, T Silver, X L Wang, S X Dou,** "Microstructures and Enhancement of Critical Current Density in $YB_{a2}Cu_3O_7$ Thin Films Grown by Pulsed Laser Deposition on Various

Single Crystal substrates Modified by Ag Nano-Dots", IEEE Transactions on Applied Superconductivity Vol. 15 No. 2 pp. 3046 -3049 (2005)

19. **R A Lewis,** "Attributes of the university graduate: How important are they?", Journal of Institutional Research", Vol 12, No 2 (2005), pp1-4.
20. **S A Needham, G X Wang, H K Liu,** "Electrochemical performance of SnSb and Sn/SnSb nanosize powders as anode materials in Li-ion cells", Journal of Alloys and Compounds, Vol 400 (2005), pp234-238.
21. **S H Ng, J Wang, Z P Guo, J Chen, G X Wang, H K Liu**, "Single wall carbon nanotube paper as anode for lithium-ion battery", Electrochimica Acta, Vol 51, pp23-28, (2005)
22. **M Roussel, A V Pan, A V Bobyl, Y Zhao, S X Dou, T H Johansen**, "Magnetic flux penetration in MgB_2 thin films produced by pulsed laser deposition", Superconductor Science and Technology, Vol 18(10), pp1391-1395, (2005)
23. **M Roussel, A V Pan, R Zeng, S X Dou**, "Influence of the final heat treatment on properties of Bi-22223 multifilamentary tapes", Physica C, Vol 425, pp135-143, (2005)
24. **D Q Shi, S X Dou, R K Ko, J K Chung, H S Kim, H S Ha, K J Song, C Park**, "YBCO coated conductor using biaxially textured clad composite Ni-Mn/Ni-Cr substrate", Superconductor Science and Technology, Vol 18(10), pp1405-1409, (2005)
25. **M D Sumption, M Bhatia, M Rindfleisch, M Tomsic, S Soltanian, S X Dou, E W Collings,** "Large upper critical field and irreversibility field in MgB_2 wires with SiC additions" Applied Physics Letters, Vol **86**(9)**,** pp092507, (2005)
26. **S Soltanian, X L Wang, J Horvat, S X Dou, M D Sumption, M Bhatia, E W Collings, P Munroe, M Tomsic** "High transport critical current density and large H_{c2} and H_{irr} in nanoscale SiC doped MgB_2 wires sintered at low temperature" Superconductor Science and Technology, Vol 18(5), pp658-666, (2005)
27. **G X Wang, L Yang, J Z Wang, H K Liu, S X Dou,** " Enhancement of ionic conductivity of PEO Based Polymer Electrolyte by the Addition of Nanosize Ceramic Powders", Journal of Nanoscience and Nanotechnology, Vol 5(7), (2005), pp1135-1140.
28. **G X Wang, S Bewlay, L Yang, J Z Wang, Y Chen, J Yao, H K Liu, S X Dou,** "Nanostructured Electrode Materials for Rechargeable Lithium-ion Battery Applications", Journal of Materials Science and Technology, Vol 21, Suppl 1 (2005), pp17-19.
29. **G X Wang, Y Chen, L Yang, J Yao, S Needham, H K Liu, J H Ahn,** "Synthesis of nanocrystalline transition metal and oxides for lithium storage", Vol 146 (2005), pp487-491.
30. **G X Wang, L Yang, S L Bewlay, Y Chen, H K Liu, J H Ahn,** "Electrochemical properties of carbon coated $LiFePO_4$ cathode materials", Journal of Power Sources, Vol 146 (2005), pp521-524.
31. **G X Wang, L Yang, Y Chen, J Z Wang, S Bewlay, H K Liu,** "An investigation of polypyrrole-$LiFePO_4$ composite cathode materials for lithium-ion batteries", Electrochimica Acta, Vol 50 (2005), pp4649-4654.
32. **X L Wang, Z W Lin, H W Lu, J G Zhu, J J Zhong, S Y Ding**, "Vector characterisation of soft magnetic materials" Journal of Applied Physics, Vol 97, pp 658-666, (2005)
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Funding 2005

Australian Research Council Grants

ARC Large/Discovery Scheme Grants

S.X Dou J. Horvat	First principles for development of high temperature superconducting wires	$203,899	
S.X. Dou M.J.Qin	Control of nano-structure for enhancing the performance of magnesium diboride superconductor by chemical doping	$100,000	
X.L. Wang	Exploration for new materials for spintronics	$210,967	
C. Zhang, R.A. Lewis	Analysis, simulation, fabrication and characterisation of reliable, robust and salable compact cooling elements based on semiconductor nanostructures	$40,000	
X.L.Wang, M.Ionescu Z.X. Cheng	Fabrication, Charge and Spin Ordering, Magnetoresistance, and polaron effects in nano-size and single crystals of novel transition metal perovskite oxide	$78,000	
H K Liu Z.P.Guo	Hydrogen storage materials for energy conversion applications	$85,000	
A V Pan	Development of hight-temperature superconducting coated conductors by pulsed-laser deposition for future long-length applications	$70,000	
A V Pan S Zhou, Y Genenko, TH Johansen	Development of new technology for coated conductors able to carry "over-critical" current densities	$125,000	
G X Wang KK Konstantinov, J Ahn, XQ Yang, Z Xiao	Synthesis of nanowires and application as nanosensors for chemical and biological detections	$80,000	
C Zhang R.A.Lewis X.Zhang R.E.Vikers	Non-linear dynamics in electronic systems and devices under intense terahertz radiation	$140,000	
			$1,132,866

ARC Centre of Excellence Grants

H.K. Liu	Nano-materials for energy storage	$213,174	**$213,174**
Sub-total			**$1,356,040**

Strategic Partnerships with Industry – (SPIRT) Scheme - Linkage Projects & Linkage APAI

S.X. Dou A V Pan	Novel electric field induced coupling technique for liquid-phase heteroepitaxial growth of carbon thin films with diamond-like structure	$12,000	
SX Dou, MJ Qin, AV Pan, X Wang, EW Collings	Development of Magnesium Diboride Superconductor Wires with High Upper Critical Field for MRI Applications	$169,612	
BS Richards, M Ionescu	Enhancing the Understanding and Performance of Passivating TiO2 Coatings for Photovoltaic Devices	$127,000	
H K Liu J Wang	Lithium/sulphur rechargeable batteries for power applications	$75,000	

G X Wang G X Wang	Large-scale rechargeable lithium battery for power storage and electric vehicle applications	$110,000	
			$493,612

Linkage International Awards

S X Dou A V Pan	Magneto-optical imaging of super-current flow in superconducting tapes and wire	$10,960	
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C. Zhang	Photon induced nonlinear absorption and transport in semiconductor nanostructures	$8,000	
X L Wang, S X. Dou J Yoo	Improvement of critical current density in MgB2 wires and tapes and Y-Ba-Cu-O coated conductors	$71,800	
C. Zhang R.A.Lewis K.A.Chao	Simulation and characterisation of opto-thermionic cooling devices	$18,700	
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Research Infrastructure Block Grants

Aleksey Pan, Shi Dou, Chris Cook, Hugh Brown, Geoff Spinks, Roger Lewis, Zaiping Guo, Jung Ho Kim, Konstantin Konstantinov, Hua Liu, Dongqi Shi, M. Qin,Guoxiu Wang, J. Wang, Chao Zhang, Sihai Zhou	Surface Profiler for Thickness Measurements and Surface Property/Quality Control	$75,000	
S. X. Dou	Laboratory Management Fellow	$74.000	
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SERDF Grants

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Small Grants & Indicative Near Miss Grants

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X L Wang	Novel ferroelectric magnetic materials for multi-functional applications	$14,500
A V Pan	Stronger pinning and larger currents for the second generation of superconducting wires based on thin film technology	$10,000
J Wang J Chen	Optimised LiFePO4 Using Conducting Polymers for Rechargeable Lithium-ion Batteries	$8,500
R A Lewis	Optical Readout Of Silicon: Phosphorous Electronic States For Quantum Computation	$14,500

G X Wang	Preparation and characterisation of functional semiconductor nanowires	$7,500	
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Australian Institute of Nuclear Science & Engineering

H K Liuu	Oxygen contamination and element depth profile in MgB2 thin films	$3,139	
A V Pan	Structure and interface control in mono- and multi-layered high temperature superconducting film	$3,139	
B Richards	Understanding the role of hydrogen in passivating amorphous silicon nitride dielectric coatings	$3,139	
S Soltanian	Study of critical current density, superconductivity, and crystal structure of bulk MgB2 prepared by the in-situ reaction technique	$6,010	
			$15,507

Industry Grants

Metal Manufactures Ltd	$64,920	
Guangzhou Delong	$15,000	
Hyper Tech Research Inc	$30,000	
SOPO Ltd	$22,000	
Alphatech International Ltd	$5,000	
		$136,920

University of Wollongong Support

ISEM Performance Indicators	$101,618	
Faculty of Engineering funding	$20,000	
URC contribution	$125,000	
Postgraduate student maintenance funds	$37,500	
Scholarships	$189,000	
		$475,118

TOTAL 2005 funding	**$2,841,957**

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