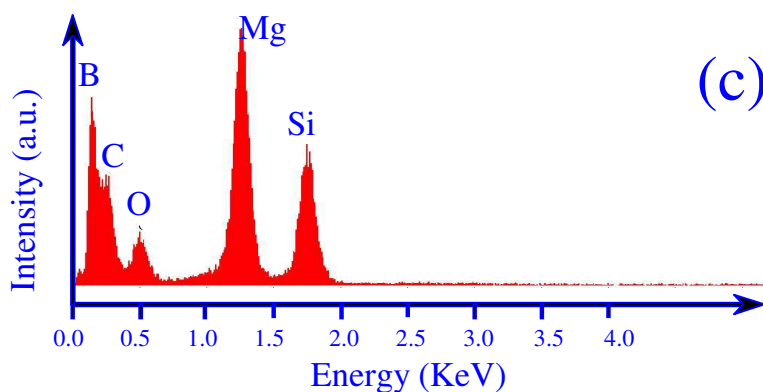
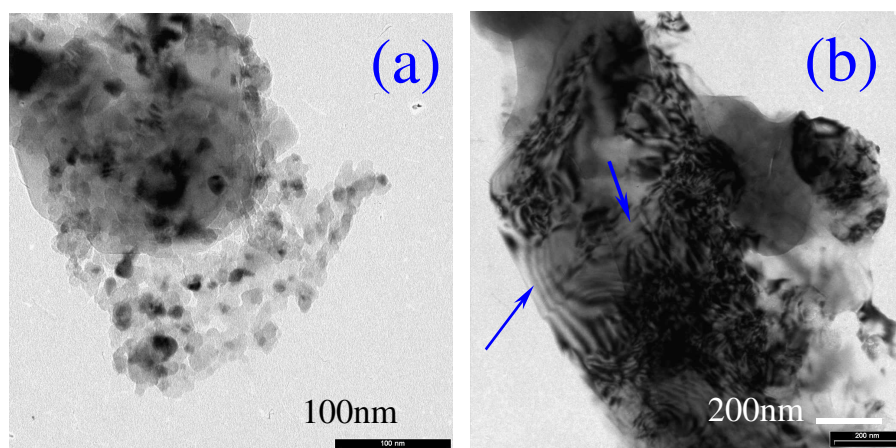


Institute for Superconducting
& Electronic Materials

Annual Report 2002



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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.

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.

Outstanding Thesis Award (Faculty Award)



G.X. Wang

Excellence Award (ISEM Award)



S. Soltanian

Postgraduate Student Merit Awards (ISEM Awards)

M. Lindsay



Z.P. Guo



K. Uprety



B. Lough



Part of ISEM's Staff & Students

Cover: TEM images (a,b) and EDX analysis (c) of the nano-SiC doped MgB_2 . The critical current density in magnetic field was enhanced by more than an order of magnitude via nano-SiC doping (S.X. Dou et al Appl. Phys. Lett. 81, 3419 (2002))

Professor SX Dou

Director

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Dr M Ionescu

Assistant Director

e-mail: mionescu@uow.edu.au

Mrs BM Allen

Administration officer

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Electronic Materials

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Energy Materials

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Assoc. Prof. C. Zhang

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Director's Report

In 2002 our institute achieved further consolidation with more than 20 different ARC projects underway and a large number of national and international collaborators and industry partners joining our exciting research endeavours.

The Superconductivity Group made a significant breakthrough in the newly discovered superconductor, magnesium diboride, achieving a record high performance of critical current density in magnetic field through the development of nano-structure defects. By doping MgB_2 with nano-particle silicon carbide, the group has successfully fabricated a series of composite Mg-B-Si-C through a reaction in-situ process. The nano-SiC doping, without much reduction in T_c allows the creation of intra-grain defects and highly dispersed nano-inclusions within the grains which can act as effective pinning centres for improving flux pinning and critical current density. Compared to the undoped sample, the critical current density for the doped sample increased by more than an order of magnitude in magnetic fields. This is the best critical current density performance in magnetic fields ever reported for MgB_2 bulk and wires. This work also shows that nano-materials hold the key to the most challenging problems relating to superconductors in particular, and to various technologies at large. Due to its high performance it is anticipated that future MgB_2 conductors will be made using the UoW formula of $\text{MgB}_x\text{Si}_y\text{C}_z$ instead of pure MgB_2 , enabling it to replace the current market leader, Nb-Ti and high temperature superconductors (HTS) in many applications such as MRI.

The Energy Storage Materials Research Group made several milestone achievements in 2002. Nanosize cobalt oxide anode materials made by the decomposition of cobalt octacarbonyl exhibit a lithium storage capacity of 800 mAh/g in the initial cycle. Microencapsulation of nanosize Sn in graphite and mesophase-microbead matrix by *in situ* chemical reduction results in a significant improvement in the anode capacity. Lithium nickel oxides and layered lithium manganese oxide cathode materials synthesised using multiple-ion-doping techniques deliver a capacity in the range of 140-180 mAh/g with fairly stable cyclability. The structure evolutions during charge/discharge were investigated by *in situ* synchrotron x-ray diffraction. A number of nanostructured intermetallic alloys such as Fe_3Al_5 , Ni_3Sn_4 and FeSi_2 have been developed for lithium storage. Two ARC linkage projects were finalised with the support from Sons of Gwalia, OM Group and Lexel Battery Ltd.

The Solid State Research Group carried out research on following areas. Theory and experimental work has been performed to understand the electronic thermal conduction across multilayered systems and to develop an optimal design for an electron cooling engine. In collaboration with the Chinese Academy of Sciences and Lund University (Sweden), several new devices were fabricated based on the simulation result. Impurity states in silicon, germanium and gallium arsenide have been investigated involving experimental measurements of the electronic and optical properties under various external conditions such as magnetic field, temperature and uniaxial forces. Recently, they have developed a spectroscopy method for the detection of various treatments of semiconductor surfaces. Some aspects of compensating silicon samples by neutron transmutional doping have also been explored. Terahertz generation and imaging involves a theoretical study of light emission on layered semiconductors and the interaction of terahertz lasers with solid state and biological materials. The group investigated the nonlinear current response in semiconductor nanostructures to intense terahertz radiation. FIR studies of CMR materials were carried out with measurements on the frequency dependent transmission and reflection of CMR materials using an FIR laser to identify various phonon modes and their coupling to the laser in these materials.

Through successful collaboration with a number of groups, our researchers have extended ISEM's research capability to new fields such as CMR materials. This is evidenced by the ARC discovery grant funding obtained by X.L. Wang, M. Ionescu, Z.X. Cheng and three partner investigators. This is also a result of close cooperation between the HTS group and the Solid Physics group over the past five years. Associate Professors C. Zhang and R. Lewis have been awarded Discovery and Linkage International projects and extended their research to a semiconductor nanostructure cooling effect that could have the potential to revolutionize cooling technology for modern electronic and photonic systems.

It is particularly pleasing that some early career researchers have quickly established their research groups. For example, Dr. X.L. Wang has successfully proposed two ARC Discovery projects and two ARC linkage projects in the last two years. Over the last three years we have made 99 National competitive grant applications, and of these, 47 were successful, an excellent success rate.

Our postgraduate student training continues improving its stature in the international research community. Twelve are in North America, two in Europe, six in Asia and the remainder in Australia. They have made significant contributions to advancements in science, technology and industry. Despite the relentless layoff in worldwide technological sectors, nearly all our new PhD graduates have received job offers from prestigious institutions. K. Uprety, X.K. Fu, Z.P. Guo, D.Q. Shi, D. Marinaro, F. Darmann and J.Z. Wang were offered research positions at Argonne National Laboratory, Texas A&M University, Texas University at Austin in USA, Korean Electrical Technology Institute in Korea, Defence Science and Technology Organisation, Australian Superconductors Ltd and the Intelligent Polymer Research Institute at University of Wollongong Australia, respectively. This year the ISEM Postgraduate Student Excellence Award was given to S. Keshavarzi for her constant dedication and endeavors to pursue theoretical and experimental research in the superconductivity field. ISEM Merit Awards were given to S. Bewlay for his dedication and hard work on improving cathode materials processing for Li-ion batteries, M. Lindsay for his invaluable contribution to IT service and computer programming at the institute, S. Soltanian and S.H. Zhou for their significant contributions to the breakthrough in nano-SiC doped MgB₂.

We continue implementing our strategy to improve our postgraduate student training program. While we have a large number of students completing in 2002 and 2003, we have been successful in attracting more to undertake their studies our institute. Thirteen new postgraduate students have joined our institute since January 2002. L. Yuan, S. Bewlay, Z.M. Zhang, Q.W. Yao, Z.J. Dou and Y. Zhao have been awarded APAI scholarships. M. Roussel and H. Sun were successful in obtaining UPA match scholarships. W.K. Yeoh was awarded an Australian Asian Scholarship. S. Keshavazi was awarded an Iranian government scholarship. Y.P. Yao, M. Farhoudi and Jerry Zhao were offered ISEM scholarships. We will continue to provide sufficient support and quality supervision to improve our student training and maintain our high profile in postgraduate student employment.

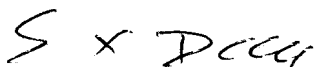
We will extend our research programs from the current three to the following five, with the new coordinators named below:

- | | |
|---|--------------------|
| (a) Applied Superconductivity | J. Horvat |
| (b) Electronic Materials (CMR, etc) | X.L. Wang |
| (c) Thin Film Technology | M. Ionescu |
| (d) Energy Materials: Battery materials, Hydrogen energy and Fuel cells | H.K. Liu |
| (e) Solid State Physics: Semiconductors, Photonics, Terahertz, Lasers | C. Zhang/P. Fisher |

Looking beyond next year our institute is facing great challenges in the domestic and international competitive environments. Our vision is to form a focussed research program on materials, specifically nano-materials for energy applications. Our strategies to achieve this include:

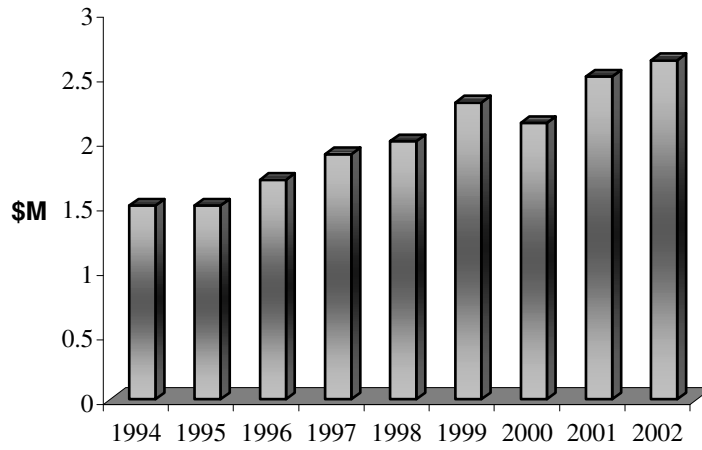
- (a) Extend our research capability to new areas of great potential: electronic materials, energy, thin film technology and photonics
- (b) Invest in PGS (>\$400K for scholarships) to increase EFTSU income (30 PGS)
- (c) Improve the quality of the research proposals for NCG (>50% success rate)
- (d) Promote the interaction and collaboration with the Schools of Engineering Physics and Materials and Mechanical Engineering
- (e) Prepare a group of research leaders for the extended programs
- (f) Enhance our international and industrial links

I have every confidence that our institute will continue to be successful in the years to come.

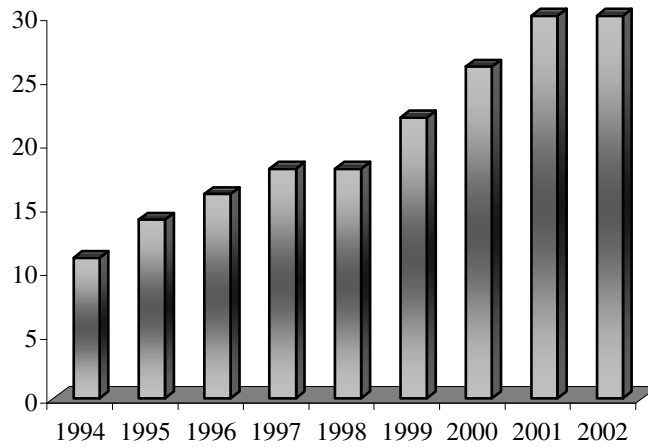


Shi Xue DOU

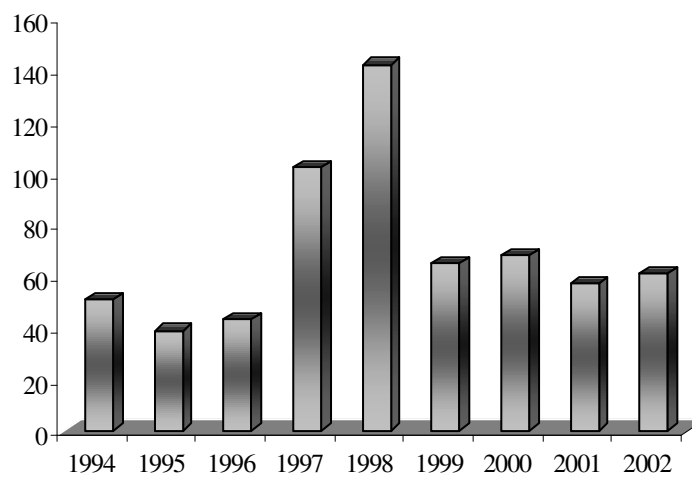
Research Grant Funds



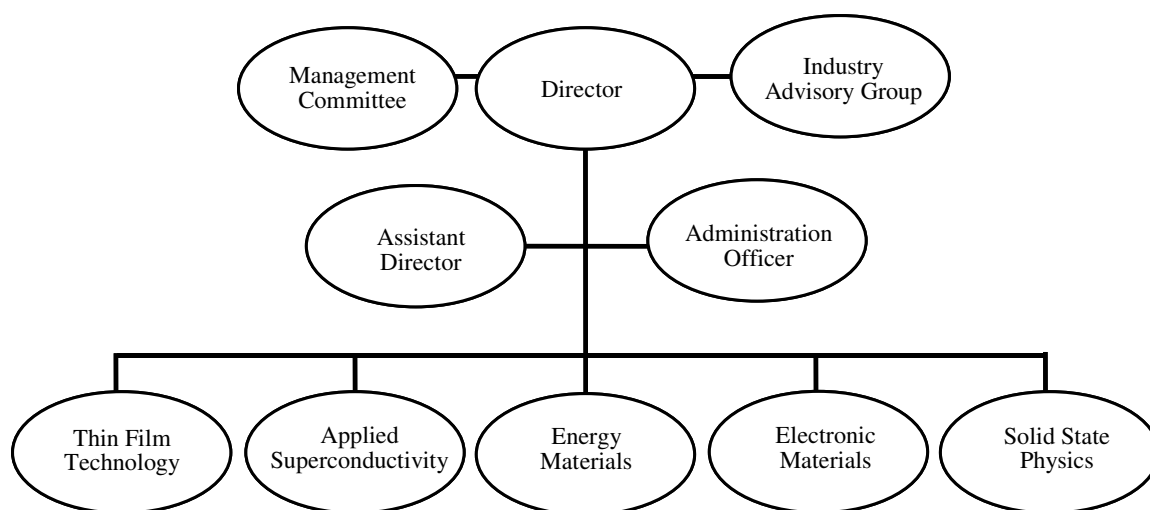
Postgraduate Student Numbers



Refereed Publications (DETYA Categories)



Management



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. H.K. Liu	Research Co-Ordinator, ISEM
	Prof. P. Fisher	Research Co-Ordinator, ISEM
	Dr. C. Zhang	Research Co-Ordinator, ISEM
	Dr. M. Ionescu	Assistant Director, ISEM

Industry Advisory Group

Dr T. Beales	Manager	Australian Superconductors Ltd, Metal Manufactures Ltd
Mr Bruce Buchtman	Advanced Syst. Engineer	Email Limited
Dr S Dunmead	Vice President for R&D	OM Group, USA
Dr. X.F. Gao	General Manager	Lexel Batteries Co. Ltd, Shenzhen, PR China
Prof. C. Fu	Managing Director	Golden Champower Co Ltd, Shenyang, PR China
Mr. R. Neale	Managing Director	Alphatech International Ltd
Dr. D. Paull	General Manager Development	Sons of Gwalia Ltd, Perth
Mr M. Tomsic	Managing Director	Hyper Tech Research Ltd, Ohio, USA,
Prof J.S. Wang	President	Taiyi Battery Co. Ltd., Zhuhai, PR China
Mr. L. Wild	Marketing Manager	Electric Transit Pty Ltd, Wetherill Park
Mr J.F. Wu	Marketing Manager	Lexel Batteries Co Ltd, Shenzhen, PR China
Dr. S. Zhong	Managing Director	Leadcel Dynamic Energy Co Ltd, Shenyang, PR China

Personnel

Director

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

Assistant Director

Dr M Ionescu, BSc, MSc, PhD

Senior Program Co-Ordinators

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

Prof. P. Fisher, BSc (Hons), PhD, MIOP, FAPS,
FAIP, Hon. AINSE Fellow

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

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

Dr. J. Horvat, BSc, PhD

Dr. X.L. Wang, BSc, 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

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

Dr. P. Majewski, ARC International Prof. Fellow

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

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

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

Administration Officer

Ms. Babs Allen

Research Staff

Dr. Z. Cheng, BSc, MSc, PhD

Dr. K. Konstantinov, MSc, PhD

Dr. A. Pan, BSc, PhD

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

Dr. T. Silver, BSc, PhD

Dr. J.X. Jin, MSc, PhD

Dr. R. Zeng, BSc, MSc, PhD

Affiliated Academic Staff:

Prof. C. Cook, BSc, PhD, FIEAust

Prof. D. Dunne, BSc, PhD, FIEAust

Dr. C. Freeth, MSc, PhD, MAIP

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

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

Dr. R.E.M. Vickers, MSc, PhD, MAIP

Visiting Staff

Prof. E.W. Collings, Ohio State University

Prof. H. Liu, Sichuan Uni, PR China

Prof G.X. Lu, South East Uni, PR China

Dr. S. Kennedy, ANSTO

Ms Marie Roussel

Dr. S. Zhong, Leadcel Dynamic Energy Ltd

Ms Ling Yuan, Lexel Battery Ltd

Technical Staff

Mr C. Rossi

Mr. R. Kinnell

Postgraduate Students

Current

High Temperature Superconductivity Group

PhD	Thesis Title	Supervisors
F Darmann	Characterisation of Melt-texture Y-123 Materials	SX Dou, T Beales, C Cook
M Farhoudi	Synthesis and characterization of transition material oxide	XL Wang, SX Dou
XK Fu	Superconducting Current Leads using Bi-based high Temperature Superconductors	HK Liu, YC Guo
F. Gao	Preparation and Characterisation of Colossal Magnetoresistance Materials	SX Dou, RA Lewis
T Green	Transport and Optical Properties in Optically Pumped Electronic Systems	W Xu, SX Dou
S. Keshavarzi	Investigation of Flux Dynamics of HTS and MgB ₂	MJ Qin, SX Dou
A Li	YBCO thick and thin films	M Ionescu, HK Liu
G Li	Numerical Analysis on Electromagnetic Behaviour of High T _c Superconductors in Magnetic Field	HK Liu, MJ Qin
J McKinnon	Y-123 Ceramic Film on Single-Crystal Substrates by Laser Ablation	M Ionescu, J Horvat
D Marinaro	Flux Pinning Mechanism in Thermal Neutron Irradiated -doped HTS	SX Dou, J Horvat
D Milliken	Enhancement of Flux Pinning through Uranium Doping and Neutron Irradiation in Bi-2223 Tapes	SX Dou, YC Guo
M Roussel	MOI of Superconductors	SX Dou, A Pan, T Johansen
S Soltanian	Characterisation of CMR Materials & MgB ₂	SX Dou, XL Wang
K Uprety	Vortex properties of Bi-HTS	SX Dou, J Horvat
Y Zhao	Fabrication and Characterization of MgB ₂ Films	SX Dou, M Ionescu
SH Zhou	Density Evaluation During Processing of Bi-2223/Ag Tape	HK Liu, A Pan
WK Yeoh	Control of Nanostructure for Enhancing Superconductor Performance through Chemical Doping	SX Dou, J Horvat
Masters		
Q Yao	MgB ₂ Thick Films	XL Wang, SX Dou
Z Zhang	Characterisation of Sheathed Bi-2223 HTS Tapes	HK Liu, M. Apperley

Energy Storage Materials Research Group

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
ZP Guo	Improvement of Energy Density and Cycle Life of Nickel Metal Hydride Batteries	HK Liu, SX Dou
M Lindsay	Anode and Cathode Materials for Lithium Ion Batteries	HK Liu, GX Wang
C Wang	Investigation of Positive Electrodes for Ni-MH Batteries	HK Liu, Prof SX Dou
JZ Wang	Bipolar Electrode Materials and Design for Electric Vehicles	HK Liu, SX Dou
L Yuan	Nano-materials for use in Li-ion Batteries	HK Liu, K Konstantinov
Masters		
J Yao	Nanocarbon tube for anode materials of Li-ion batteries	HK Liu, JH Ahn
ZW Zhao	Spray Pyrolysis Technique for Processing Cathode Materials	K Konstantinov, HK Liu

Solid State Physics Group

PhD	Thesis Title	Supervisors
D Fisher	Dissipation Effect in Resonant Tunnelling through Double Barrier Structures	C Zhang
B Lough	Thermionic Cooling with Semiconductor Multilayers	RA Lewis, C Zhang
ZJ Dou	Thermionic Cooling for Domestic Refrigeration	RA Lewis, C Zhang
SH Pilehrood	Electronic Properties of Semiconductor Nanostructures under Intense Terahertz Radiation	C Zhang
Masters		
K. Ishida	Solid State Spectroscopy	P Fisher, REM Vickers
PS Lavers	The Mobility of Large Anions in Crystals with the Fluorite Structure	AD Martin
S Lee	Multilayer thermionic cooling in semiconductor heterostructures	RA Lewis, C Zhang
H Ta	Electronic Properties of Modulated Two Dimensional Semiconductors	C Zhang

Completions

PhD Name & Thesis Title	Awarded	Position	When Appointed
M Apperley The Fabrication of High T _c Superconductor Wire	1992	Chief Technologist Australian Superconductors	1993
R Baker Zeeman and Piezospectroscopy of Antimony and Aluminum 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
XK Fu Superconducting current leads using Bi-HTS	2002	Research Fellow Texas A&M University, USA	2002
YC Guo Investigation of Silver-clad (Bi,Pb) ₂ Sr ₂ Ca ₂ Cu ₃ O _{10-x} Superconducting Tapes	1994	STA Fellow Nat. Res. Inst. Of Metals, Japan ARC Postdoctoral Fellow ISEM, University of Wollongong	1997 1998
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 ₂ Sr ₂ Ca ₃ Cu ₃ O ₁₀ Tapes	1996	Research Fellow Florida State University USA Research Scientist Argonne National Lab., USA Senior Engineer, Lucent, USA	1997 1999 2001
M Ionescu Growth and Characterisation of Bi-2212 Crystals and Improvement of Bi-2212/Ag Superconducting Tapes	1998	Assistant Director ISEM, University of Wollongong	1994
JX Jin (Bi,Pb) ₂ Sr ₂ Ca ₂ Cu ₃ O _{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
M Lerch Optical & Electrical Studies of Resonant Tunnelling Heterostructure	1998	Research Fellow Medical Physics	1999
BL Luan Investigations on Ti ₂ Ni 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

PhD Name & Thesis Title	Awarded	Position	When Appointed
D Shi Investigation of Buffer Layer for Y-123 Coated Conductor Using Laser Ablation	2002	Research Fellow Korean Electrical Technology Institute, Korea	2002
T Silver Near Bandedge Optical Properties Of MBE GaAs And Related Layered Structures	1999	Research Fellow ISEM, University of Wollongong	2000
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	1998 1999
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 2 nd Year Physics Lab	1999
K. Uprety Vortex Properties of Bi-HTS	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 Intermagetics General Co., USA	1999 1998
GX Wang Investigation on electrode materials for lithium-ion batteries	2001	ARC Postdoc. Fellow ISEM, University of Wollongong	2001
WG Wang Fabrication And Improvement Of Silver Sheathed (Bi,Pb) ₂ Sr ₂ Ca ₂ Cu ₃ O 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	1999 2002
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
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	2000 1997
B Zeimetz High Temperature Superconducting Tapes & Current Leads	1998	Research Fellow Cambridge Univ., U.K.	1999

PhD Name & Thesis Title	Awarded	Position	When Appointed
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	1997 2002
R Zeng Processing and characterisation of Bi-2223/Ag superconducting tapes	2000	Research Fellow ISEM, University of Wollongong	2000

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 of Ag/Bi-2223 Tape in AC Field	2002	PhD candidate ISEM, University of Wollongong	2003
JX Jin (Bi,Pb) ₂ Sr ₂ Ca ₂ Cu ₃ O _{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
A Li Novel substrates for Bi-Sr-Ca-Cu-O superconducting	2002	PhD Candidate ISEM, University of Wollongong	2002
M Ling Mechanism of Outgrowth in Multifilament Bi-2223 tape	2001		
E. Sotirova Investigation of Colossal Magnetoresistance Materials	2001	Learning Centre Employee Communications Assistant Star CD Pty Ltd	2002
K Uprety Vortex Properties of Bi-HTS	1999	PhD Candidate ISEM, University of Wollongong Research Fellow Argonne National Lab., USA	2000 2003
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
N Zahir A New Method for Production and Study of Electrical Properties of Carbon Foam	1996	PhD Candidate Queensland University	1997

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. The current collaborative organizations are listed below:

Australia

Australian Nuclear Science & Technology Organisation

Australian National University, Canberra

University of Sydney

Curtin University of Technology

Macquarie University

University of Technology, Sydney

Monash University

University of Melbourne

University of New South Wales

James Cook University

University of Queensland

Dr. S. Kennedy, Dr. M. James,
Dr M. Reinhard

Dr. M. Das

Dr. S. Ringer, Dr. R. Keast

A/Prof. J Low

A/Prof. E. Goldys

Prof. G. Smith

Dr. Y.B. Cheng, Krishnamurthy

Prof. D. Jamieson

Dr. R. Ramer, Prof. M.S. Kazakos,
A/Prof. P. Munroe

Prof. J. Mazierska,

Prof. G.Q.M. Lu

International

Atomic Institute of Austrian Universities, Vienna, Austria

Brookhaven National Lab

Dalhousie University, Canada

Houston University, USA

Institute for Metal Physics, Kiev, Ukraine

Ludwig Boltzmann Institut für Festkörperphysik,

University of Vienna, Austria.

Max-Planck Institute for Metals Research, Germany

Max-Planck Institute for Solid State Physics, Germany

Nankai University, PRC

Nanjing University

Nanyang Technological University

National Andong University

Northeastern University, Shenyang, PRC

Ohio State University, Columbus, OH, USA

Osaka National Research Institute, Japan

University of Auckland

University of Cincinnati

University of Wisconsin

University of Zagreb, Zagreb, Croatia

Yamagata University, Japan

Kyushu Institute of Technology

Institute of Physics, Chinese Academy

University of Geneva

Korean Advanced Institute of Science & Technology

City Polytechnical University, Hong Kong, China

Prof. H.W. Weber

Dr. X.Q. Yang, Dr. Y.M. Zhu

Prof. J. Dahn

Prof. R. Weinstein

Prof. V. Pan

Dr. W. Lang

Dr. E.H. Brandt, Dr. P. Majewski

Prof. U. Habermeier

Prof. J. Chen, Prof. Y.H. Tang

Prof. S.Y. Ding, Prof. W.M. Chen

Prof. S. Li

Prof. J.H. Ahn

Prof. Y.C. Zhai

Dr. E.W. Collings, Dr. M. Sumption

Dr. T. Sakai

Prof. W. Gao

Prof. D. Shi

Prof. D. Larbalestier, Dr. A. Polyanskii

Prof. E. Babic, I. Kusevic

Dr. S. Kambe, Prof. Ohshima

Prof. T. Masushita

Prof H.H. Wen

Prof. R. Flukiger

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Progress Reports for Projects funded by the Australian Research Council

1. Progress Reports on ARC Large/Discovery Projects

Study of current limiting mechanisms in Ag sheathed (Bi,Pb)SrCaCuO tapes using magneto-optical imaging and magnetic force microscopy

Funded:	2000	2001	2002
Project ID:	A10012023		
Chief Investigator:	H.K. Liu		
Assoc. Investigators:	A. Polyanski, J. Horvat, D. Labalestier		

The local magnetic flux distribution in the superconducting core of Bi-2223 tape has been investigated by employing a combination of local magneto-optical (MO) imaging and global magnetization measurements: We find a strong correlation between the local magnetic flux behavior and overall J_c derived from the global magnetization measurements. Below B^* , J_c as a function of applied magnetic field exhibits an B_a -independent plateau, whereas below this field it starts to degrade. Generally, the frozen magnetic flux is distributed in a highly inhomogeneous way inside the core. This is simply due to large-scale cracks most likely introduced either by the manufacturing procedure or by the subsequent handling of the sample, in particular, during the sheath removal. On decreasing the applied field, local changes in the magnetic distribution inside the core are visible at the "boundary" regions down to B^* . This is due to the fact that the magnetic flux near the edges leaves the superconductor in agreement with the critical state model. Below B^* and down to $B_a = 0$ T, we could not detect any change in the local flux distribution over the core. This implies that the critical state achieved at B^* does not change within the sample below this field: vortices neither move nor leave the core. Therefore, below B^* the vortices are firmly pinned. Whereas above B^* vortex-vortex interactions are important, hence the pinning of individual vortices is weaker, allowing a crossover from the collective regime above B^* with rapidly degrading J_c to stronger individual vortex pinning below B^* . This conclusion is supported by qualitative analysis of vortex interactions arising from the average inter-vortex distance at B^* .

The strong $B^*(T)$ dependence is suggested to be due to thermally activated depinning of individual vortices. The higher the temperature is, the more sensitive the vortices become to a thermally activated environment. As a consequence, the value of B^* rapidly decreases as a function of temperature.

Direct visualization of the iron sheath shielding effect in Fe-sheathed mono-core and multi-filamentary MgB_2 superconducting wires has been investigated using local magneto-optical and global magnetization measurement techniques. We found that there is almost no difference between the MO images taken in either the normal or the superconducting state at $B_a \leq 0.1$ T, indicating a the strong magnetic shielding effect. The magnetic field starts to concentrate at the edges of the wire and, as B_a is increased, the induced field inside the samples is accumulated only in the Fe-sheath. At $B_a > 0.1$ T, a discrepancy between images taken at RT and 19 K becomes visible. At RT, a bright stripe of the induced field appears in the middle of the exposed core due to the geometry of the open core cavity. The stripe disappears in the images taken in the superconducting state ($T = 19$ K). This is because in the normal state, MgB_2 material is transparent to the magnetic field, having no influence on the distribution of the field. On the contrary, in the superconducting state at $T = 19$ K, the core is strongly diamagnetic, in particular, below the lower critical field B_{c1} . Therefore, the magnetic field is expelled from the interior of the core and the stripe vanishes. The induced field B_i in the area is effectively zero. In spite of the fact that the wire is placed in $B_a > B_{c1}$, the core is entirely diamagnetic at $T < T_c$, with the exception of some brighter regions close to the sheath. In these regions B_i is not equal to zero due to some trapped flux in cracks and voids in the core.

5 papers from this project were published in 2002.

Enhancement of critical current density and flux pinning in BiPbSrCaCuO systems by fission tracks

Funded:	2001	2002	2003
Project ID:	A00104022		
Chief Investigator:	S.X. Dou		
Research Fellow:	T. Silver		
Postgrad. students:	D. Marinaro, D. Milliken		

The objective of this project is to enhance flux pinning in bismuth based high temperature superconductors (BSCCO HTS) by using a combination of stable uranium compound doping and thermal neutron irradiation to produce fission fragments to act as pinning centres. The enhanced flux pinning is expected to lead to improved J_c in magnetic fields and minimised anisotropy of HTS compounds.

Preliminary work had been done in identifying uranium impurity phases that occur in uranium oxide doped BSCCO and similar compounds, as such compounds are already fully reacted and are likely to be stable. These were synthesised and tested for chemical compatibility with BSCCO. The leading candidate was determined to be $UCa_{1.5}Sr_{1.5}O_6$. The compound was then made from 93% enriched UO_2 supplied by ANSTO, allowing the uranium compound content of the subsequent tape to be reduced. It was found from particle size analysis with a Mastersizer that 24 h ball milling reduced the particle size of the $UCa_{1.5}Sr_{1.5}O_6$ to 0.3 micron meter, the same as the Bi-2223 precursor powder, which facilitates homogeneous mixing. 1 wt % and 2 wt % U doped silver clad Bi-2223 tapes were made by a powder-in-tube (PIT) technique developed at ISEM.

The effects of the Uranium-doping and neutron irradiation treatment on the broadening of the resistive transitions and the calculated activation energies demonstrate the strong pinning of the induced fission-fragment damage. In magnetic fields $H < 1$ T applied perpendicular to the c-axis of the superconductor grains, the columnar defects provide a limited increase in the pinning energy. With the fields applied parallel to the c-axis, however, the pinning is substantially increased up to $H \sim 700$ mT, tripling in magnitude at 300 mT, and then re-converging with the pre-irradiation U_0 at $H \sim 1$ T. The results confirm the conclusion that fission-induced columnar defects act as strong pinning centres, and thus can provide a useful method for improving the flux pinning of Ag/Bi2223 tapes produced in commercial quantities

We also tried the U/n method on the new superconductor MgB_2 . The doping involved mixing 2 micron UO_2 particles with the magnesium and boron before sintering. There were no chemical reactions, and the uranium particles were located on the grain boundaries of the MgB_2 . We used isotopically pure boron-11, to avoid neutron absorption. There were some modest negative effects on J_c due to the doping at 1 wt% U. Unfortunately the neutron irradiation did not result in fission tracks, although gamma ray spectroscopy has revealed that the ^{235}U atoms in the sample did fission (and were not absorbed by the residual boron-10).

I. Kusevic, Z. Marohnic, E. Babic, D. Drobac, X.L. Wang and S.X. Dou "Flux pinning and critical currents in polycrystalline MgB_2 " *Solid. State Communs.* 122 347-350 (2002)

T. Silver, A. Pan, M. Ionescu, M. Qin and S.X. Dou "Developments in high temperature superconductivity" *Annual Reports on the Progress of Chemistry*, 9, Section C, 323-373 (2002).

B. Rout, J. Hendriks, D.N. Jamieson, R. Szymanski, D. Milliken, and S.X. Dou, "Nuclear microprobe analysis of U-doped $(Bi,Pb)_2Sr_2CaCu_3O_y/Ag$ superconducting tapes", *Nuclear Instruments & Methods in Physics Research Section B* 190 (2002) 357-364

Growth, characterization, and flux pinning behaviour of doped $TlSr_2Ca_2Cu_3O_y$ and $TlSr_2CaCu_2O_y$ high temperature superconducting single crystals

Funded:	2001	2002	2003
Project ID:	A00103044		
Chief Investigator:	H.K. Liu		
Assoc. Investigator:	M. Ionescu & X.L. Wang		
Research Fellow:	Z.X. Cheng		

(Tl,Pb)(Sr,Ba)₂Ca₂Cu₃O_y single crystal with $T_c = 110$ K and dimensions of $650 \times 405 \times 154 \mu\text{m}^2$ has been studied. Magnetic hysteresis loop and relaxation measurements were performed on a SQUID magnetometer (Quantum Design MPMS 5 T). The sample was first zero-field cooled to the desired temperature below T_c , and the magnetic field was then applied parallel to the c-axis of the single crystal. The initial magnetization was recorded after a delay time of 120 s. A scan length of 4 cm was selected to avoid any field inhomogeneity. Since the peak effect is temperature dependent and the maximum accessible field in MPMS is 5 T, this effect, which is broad, is observable from 15 K to 60 K. Magnetic relaxation measurements at low field (less than 3 T) were possible up to 65 K, but at higher field this measurement was restricted to 45 K due to dramatic fluctuations. The irreversibility line was determined from the merging point of the field cooled and zero field cooled curves collected in the warming up process. The irreversibility line can be best fitted by a quadratic function of $(1-T/T_c)$ within the field range 0-3.5 T. Magnetic relaxation was measured after we first increased the field to 5 T and then decreased it to the measurement field at each temperature to ensure full penetration.

The flux dynamics of (Tl,Pb)(Sr,Ba)₂Ca₂Cu₃O_y single crystal have been investigated by means of magnetic relaxation measurements, with the applied field parallel to the c-axis. A power law dependence of the activation energy on the current density for fields less than 2 T over the temperature range 15-45 K has been observed, consistent with three dimensional (3D) large bundle vortex creep. For intermediate fields (2-3 T), the flux dynamics are dominated by plastic vortex creep, while for fields higher than 3 T over the temperature range 16-46 K, the vortex glass scaling approach implied a two dimensional (2D) vortex structure. Using magnetic loop and relaxation measurements on a (Tl,Pb)(Sr,Ba)₂Ca₂Cu₃O_y single crystal, we observed the peak effect. The flux dynamics below and above (but near) the peak can be described by 3D collective vortex creep and plasticity (probably governed by dislocation mediated flux creep), respectively.

For fields far above the peak a 2D VG scaling leads to a good alignment of $E(J)$ curves which means that the 3D vortex system undergoes a dimensional crossover. The 3D-2D crossover field has been determined to be 3 T at 40 K. This observation shows that even low anisotropic superconductors may undergo a crossover to at least a quasi-2D vortex system.

The recent discovery of superconductivity in MgB_2 has attracted great scientific and industrial interest. To get exact data on the basic physical parameters, such as the superconductor transition temperature, magnetic hysteresis and even the mechanisms of the superconductivity, the study of MgB_2 single crystals is very important. We have developed a growth method at relatively low temperature and low pressure. By using copper as the flux and an iron tube as the container, single crystals of magnesium diborate have been successfully grown. Preliminary magnetic AC susceptibility measurements of the flux bars containing MgB_2 single crystals shows that the superconductor transition of the single crystal begins at 39.28 K. The highest reported T_c and narrow transition width lead to the assumption that the crystals are close to the stoichiometric composition. Because the crystals are not large enough to be taken out of the flux, we will try to grow larger single crystals in the near future. In this process the main problem to be solved is the conflict between the oxidation of magnesium and long time needed for the larger crystals to be grown.

Sh. Keshavarzi, M.J. Qin, X.L. Wang, H.K. Liu and S.X. Dou, "Dimensional crossover via plasticity in (Tl,Pb)(Sr,Ba)₂Ca₂Cu₃O_y single crystal", submitted to Physica C.

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. Investigator:	H. Weber, E.W. Collings, E. Habermier				

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.

Magnetic vortex dynamics was studied by the means of magnetic relaxation and transport measurements in Bi2223/Ag tapes, doped with UO₂ and irradiated with thermal neutrons. A change of the type of vortex dynamics was obtained at a characteristic magnetic field, as the field was increased. This characteristic field was almost doubled after neutron irradiation. Associated with this, there was a qualitative change in the temperature scaling term at the characteristic field. The conclusions based on all types of measurements were consistent with each other. Our analysis clearly showed that the vortex coherence along the c-axis increases with the introduction of splayed defects, contrary to recently published results where an erroneous analysis was used. Two papers on this topic are in preparation.

To take advantage of high T_c at 39K it is essential to enhance the performance of MgB₂ in magnetic fields by improving the flux pinning strength at 20K or above. We developed a novel chemical doping process to effectively introduce flux pinning centres into MgB₂. By doping MgB₂ with nano-particle SiC, we have successfully fabricated a series of compounds of Mg-B-Si-C through a reaction in-situ process. We have demonstrated that the co-substitution for B by nano-particle SiC counterbalanced the negative effect of the single element doping on T_c, introduced high density defects and nano-inclusions within the grains and enhanced J_c and H_{irr} significantly. Compared to the undoped sample, the critical current density for the doped sample increased by more than an order of magnitude. This is the best critical current density performance in magnetic fields ever reported for MgB₂ wires and bulk. Because of the high performance, and the abundance and the low costs of Si and C it is anticipated that in the future MgB₂ conductors will be made using the UoW formula of MgB_xSi_yC_z instead of MgB₂. Four refereed papers have been published on this project.

S.X. Dou et al., "Substitution-induced pinning in MgB₂ superconductor doped with SiC nano-particles" Supercond. Sci. Technol. 15, 1587-1591 (2002)

S.X. Dou et al., "Enhancement of the critical current density and flux pinning of MgB₂ superconductor by nanoparticle SiC doping" App. Phys. Lett. 81, 18, 3419-3421 (2002).

S. Li et al. "Intrinsic nanostructural domains: Possible origin of weaklinkless superconductivity in the quenched reaction product of Mg and amorphous B" Appl Phys. Lett. 81, 5 874-876 (2002)

J.K.F. Yau, M.J. Qin, H.K. Liu, S.X. Dou et al., "Pinning characteristics of MgB₂ near the melting curve", Supercond. Sci. Technol. 15, 619-623 (2002)

Enhancement and elucidation of flux pinning in doped Bi-Sr-Ca-Cu-O high temperature superconducting single crystals

Funded:	2002	2003	2004
Amount Funded:	\$61,184	\$62,967	\$62,967
Total Funding:	\$187,118		
Project ID:	DP0211328		
Chief Investigator:	X.L. Wang		

Fe and heavily Pb and Pb+Y co -doped Bi2212 crystals have been grown using conventional (2D) self-flux and TSFZ techniques and used for physical property investigations. These crystals have been characterised using X-ray diffraction (XRD), and transmission electron microscopy (TEM). Single phase crystals without any intergrowth were observed. Large numbers of defects have been observed using TEM. The defects act as effective pinning centres in the Pb doped crystals.

Annealing effects on the phases, structures and superconductivities have been studied using transport measurements (R-T) and magnetic measurements in cooperation with collaborator, Prof. W. Lang at University of Vienna as planned in project. It was found that after annealing in oxygen and re-annealing in argon, crystals changed from non-superconducting to superconducting. Phase segregation into Y-rich and Y-poor domains may take place.

The carrier concentrations in both Pb and Y doped crystals have been determined by edge X-ray absorption near edge structure (XANES) using synchrotron radiation facilities in cooperation with Prof. R.S. Liu, National Taiwan University, as planned in the project. It was found that the hole concentration was increased after annealing in oxygen.

Magnetic hysteresis and magnetic relaxation measurements have been performed to study vortex pinning behaviours for pure, Fe doped and heavily Pb doped Bi2212 single crystals. Unlike pure and Fe doped Bi2212 crystals, heavily Pb doped crystal showed strong vortex pinning behaviour. We interpret the strong pinning in heavily doped Bi2212 crystal as arising from improved Josephson coupling in the Bi2212 single crystal after heavily Pb doping. In heavily Pb doped Bi2212 crystals, $H_{dis}(T)$ was observed to decrease with increasing T. Here, $H_{dis}(T)$ is an order-disorder field that separate a weakly elastically disordered vortex lattice from a plastically disordered vortex solid. However, in pure and Fe doped Bi2212 single crystals, $H_{dis}(T)$ was observed to be temperature independent. We also report a significant shift of T_{cr} , a crossover temperature separating the two pinning regimes, towards higher temperatures with heavy Pb doping of Bi2212 single crystals. On the other hand T_{cr} did not shift with Fe doping of Bi2212 single crystals. It is argued that the temperature dependence of $H_{dis}(T)$ and the shift of T_{cr} in heavily Pb doped Bi2212 crystals was related to the enhanced c-axis conductivity caused by the Pb situated between the CuO_2 layers and imposing a 3D characteristics on the vortex lattice.

2. Progress Report on ARC Fellowships

Optimization of thermal- and mechanical processing and critical current density of high T_c superconducting Ag-clad Bi(Pb)SrCaCuO tapes

Senior Research Fellowship Project

Funded:	1999	2000	2001	2002	2003
Project ID:	F89905267				
Chief Investigator:	H.K. Liu				

The growth mechanism of Bi-2223 phase has been studied using Multi-filamentary Ag/Bi-2223 tapes manufactured by the powder-in-tube (PIT) method. X-ray powder diffraction was performed to analyse the development of the Bi-2201, Bi-2212 and Bi-2223 phases during sintering periods at high temperatures. Transmission electron microscopy (TEM) was used to analyse the growth mechanism of 2223 phase. TEM images indicated that 2201 and Ca_2CuO_3 crystals come together to form platelets of 2223. The structural phase transformation established a structural frame of 2223 crystals. There were some vacancies remaining in the established 2223 crystal cells at copper and oxygen sites after the phase transformation, and the Cu/O compound would diffuse into 2223 cells at high temperatures and occupy the corresponding vacancies to complete the 2223 crystal structure. The present work provides evidence for the growth of 2223 phase from 2201 phase and Ca_2CuO_3 . This growth mechanism is significant for studying the dynamics of 2223 crystal growth, and it may also offer a new route to approach the growth of 2223 phase in different forms, such as thin films and single crystals.

The pinning force density of the Ag/Bi-2223 tapes manufactured with an intermediate deformation, by the methods of sandwich rolling (SR), pressing (P) and normal rolling (NR) has been studied. Experimental results showed that the critical current densities (J_c) of Ag/Bi-2223 tapes depended on their reduction rate for the three deformations. J_c values of Ag/Bi-2223 tapes manufactured by SR, P and NR reached their maximum at reduction rates of 22%, 25% and 23%, respectively. The pinning force density strengths F of SR-, P- and NR-tapes were calculated for B//ab and B//c, respectively. The experimental results showed that self-field- J_c values were linear with respect to the relative density for SR-, P- and NR-tapes. But the slopes of the linearity were different for the three deformations. SR tape had the largest value of slope, while P and NR were second and third, respectively. Then maximums of pinning force density were different for SR-, P- and NR-tapes. The force density maximum of SR was a little larger than that of P, but both SR and P had much larger maxima than NR for B//ab and B//c. The irreversible magnetic field B_{irr} of SR-, P- and NR-tapes followed a similar trend. SR-tape had the highest B_{irr} , P- the second and NR the smallest. As compared to pressing and normal rolling, the above experimental evidence supported sandwich rolling as the best intermediate deformation method to improve the J_c of Ag/Bi-2223 tapes.

The magnetization hysteresis loop $M(H)$ and AC susceptibility (ACS) of type-II superconductor strips with a geometric barrier have been calculated. When a perpendicular magnetic field is applied to a finite thickness sample, the curvature of the penetrating flux lines, which leads to a geometric barrier, is evident only at very small magnetic fields. At high magnetic fields, the curvature of the penetrating flux lines is negligible, so the geometric barrier is observed only at very low fields near H_{c1} , the lower critical fields. These two conditions happen to be met in AC susceptibility measurements, where the transition is at high temperature just below T_c and the AC field amplitude is usually below 10 Gs. So it is expected that AC susceptibility measurements can be used to observe the geometric barrier. We have found that the geometric barrier has a prominent effect on both the magnetization hysteresis loops and third harmonic AC susceptibility measurements. ACS shows quite different behaviours for pinning dominated and geometric barrier dominated superconductors, which can be used to experimentally distinguish between pinning mechanisms in type-II superconductors.

7 papers from this project were published in 2002.

3. Progress Report on SPIRT/Linkage Programs

Investigation of Bi-2223/Ag Superconductor Winding for Application in an Electrical Fault Current Limiter

Funded:	2000	2001	2002
Project ID:	C00001903		
Chief Investigator:	S.X. Dou		
Partner Investigator:	M. Apperley		
Industry Partner:	Australian Superconductors (Metal Manufactures Ltd)		
Research Fellow:	J.X. Jin		
Assoc. Investigators:	C. Cook, C. Grantham		

The research objective is to study $(\text{Bi,Pb})_2\text{Sr}_2\text{Ca}_2\text{Cu}_3\text{O}_{10+x}$ Ag-clad wire for use as a dc bias winding for an inductive fault current limiter (FCL). The electrical performance of this HTSC FCL will be studied to develop an applicable device. The dc winding current-ampere turn, winding configuration, and magnetic field will be studied in relation to the FCL and HTSC wire performance. The HTSC wire critical current degeneration under this operation with cooling systems will be analysed to identify whether the HTSC wire can be operated practically and economically to meet the requirements of this electrical application.

During Year 3 the construction and assembly of the 160KVA FCL was completed. Delays were experienced in receiving the cryostats to house the high temperature superconductor (HTS) winding and this limited the amount of final testing and analysis to a basic level. High strength, Ag alloy sheathed BSCCO HTS tape was fabricated and supplied by Australian Superconductors. 1000 metres of tape was used in the winding of 2 DC bias coils each comprising 8 layers with a total of 288 turns. The overall dimensions of the coils were diameter 186 mm and length 180 mm. Interlayer insulation was provided by a Kapton and cryogenic epoxy composite that was consolidated by curing at an elevated temperature for several hours. This curing process imparted sufficient strength to the HTS tape/kapton/epoxy composite so that it could withstand handling during assembly and also withstand multiple quenching cycles during use. The I_c (at 77K and self field) of the coils were measured after curing and measured to be 70 Amps which was consistent with the design specification and the use of three tapes in parallel.

Following the successful demonstration of a prototype glass fibre reinforced plastic (GFRP) cryostat in Year 2, two full scale GFRP cryostats were designed for the FCL. These cryostats were made from a high-performance cryogenic grade epoxy and had a vacuum wall design that could be pumped-on to minimise heat leakage into the cryostat. Cryostat lids that supported the HTS coils were designed and constructed.

Assembly of the FCL was completed by attaching the HTS coils to the cryostat lids and inserting these coils into the cryostats that had been positioned around the iron core. The cryostats were sealed and the top yokes of the iron core positioned to complete the magnetic circuit. A purpose built ac power supply was connected to the FCL by flexible power cables specifically prepared for the device. A dc power supply and data acquisition system were also prepared to enable the system to be demonstrated and analysed. After the FCL was assembled, the I_c of the coils was re-tested in-situ with the GFRP cryostats and found to be 70 A which was consistent with previous measurements.

High energy batteries for electric vehicles

Funded:	2000	2001	2002
Project ID:	C00001879		
Chief Investigator:	H.K. Liu		
Assoc. Investigator:	D.H. Bradhurst, S. Zhong		
Industry Partner:	Electric Transit Ltd Australian Batteries Technology Ltd, China Liaoning Suppo Battery Ltd		
Postgrad. Student:	C.Y. Wang		

Three types of test electrodes (conventional wet-pasted electrodes, dry powder electrodes and dry powder electrodes with addition of a conductive binder of 5 wt.%) have been investigated. All three types of electrode substrates were obtained by cutting a copper-indium alloy mesh (for the dry powder electrode) or a nickel mesh (for the wet-pasted electrode). The copper-indium alloy mesh was provided by the Tai-Yi Battery company Ltd (one of the industry partner). The dry powder electrode without binder showed a poorer cycle life (30 cycles) in open test cell than the pasted electrode. However, further experiments were performed on sealed commercial AAA type cells with a nominal capacity of 550 mAh. A cell with conventional pasted Ni-H electrode and another cell with the dry powder Ni-H electrode with binder additive were investigated. The cycle life was significantly prolonged in these sealed cells. To explore the causes of cell failure, before and after the cycling tests, the sealed commercial cells were disassembled and then analyzed. The appearance of the different electrodes before and after cycle testing was compared. It was observed that the active material from the pasted Ni-H electrode dropped off easily from the electrode substrate after cycling. It was considered that negative electrode material drop-off was the main cause for the cell failure. For the pasted electrode, the cell capacity declined to 80% of its original capacity after ~260 cycles. The appearance of the electrode prepared by the dry pressing process was much more compact than for the pasted electrode material. With the addition of conductive binder, the dry powder compression process significantly increased the coherence between the active material and the electrode substrate.

After cycling for ~690 cycles, the dry powder compressed electrode was examined by SEM. A loose particle appearance was observed and indicated that the coherence between the metal-hydride particles had decreased. When viewed in cross-section, obtained by cutting the electrode for SEM sample preparation, it could be seen that the active material of the compressed electrode was still firmly coherent with the electrode substrate after cycling for ~690 cycles. This kind of coherent force is due to the hard metal-hydride particles inlaid into the relatively soft surface of the copper substrate by the high compressive force used in the preparation process for the dry powder electrode. This particle inlay force is much stronger than the particle-to-particle binding force for the pasted type of electrode and could be responsible for the substantial improvements observed in the cell capacity and service life of the dry powder pressed electrode.

At different temperatures (-15⁰C, 0⁰C, room temperature (RT) and 50⁰C), the electrochemical characteristics of Al – substituted, Al, Co – substituted nickel hydroxide and commercial spherical nickel hydroxide were investigated. Al – substituted nickel hydroxide shows the best electrochemical characteristics at all four temperatures. Its charge plateau is 110mV lower than that of the commercial sample at the temperatures of -15⁰C and 50⁰C, and 50mV and 20mV lower at 0⁰C and RT. Its discharge plateau voltage is 80mV higher than the commercial sample at 0⁰C and RT, and 131mV and 55mV higher at -15⁰C and 50⁰C. Al – substituted nickel hydroxide also shows the highest discharge capacities of 292, 318, 308, 201mAh/g at -15⁰C, 0⁰C, RT, and 50⁰C, while 153, 265, 255, 201mAh/g at -15⁰C, 0⁰C, RT, and 50⁰C were obtained for the commercial sample. Al – substituted nickel hydroxide still keeps its α - phase structure after 200 charge/discharge cycles as is clear from the X- ray diffraction pattern. The conclusion can be drawn that Al – substituted nickel hydroxide presents promising electrochemical characteristics, especially at the high and low temperatures 50⁰C and -15⁰C, which are much more important for the battery industry.

4 papers from this project were published in 2002.

Solid-state rechargeable lithium batteries for telecommunication and portable electronic devices

Funded:	2001	2002	2003
Project ID:	C00107603		
Chief Investigators:	G.X. Wang, H.K. Liu, S. Zhong		
Assoc. Investigator:	X.Q. Yang		
Industry Partners:	Australian Battery Technology, Lexel Battery Ltd.		

Ball milled nanocrystalline and subsequently annealed microcrystalline Ni-57 wt% Sn alloy have been prepared and studied to determine the Li-storage properties. As expected, the ball-milled nanocrystalline Ni-57 wt% Sn alloy exhibited high capacities as an anode active material for Li-ion batteries. The ball-milled nanocrystalline electrode can deliver a lithium storage capacity of about 1500 Ah/kg during the first cycle. However, the cyclic properties were degraded for the ball-milled nanocrystalline electrode contrary to the case of tin oxides, while they were well retained for the annealed microcrystalline electrode. The large capacity loss at the first cycle and capacity fading during cycling were observed in comparison to the microcrystalline electrode. This may be caused by the decomposition of electrolyte, the trapping of Li ions by host atoms, serious aggregation of active particles during electrochemical cycling, and especially, the existence of impurity phases. The ball milled nanocrystalline powder contains NiSn phase and minor phases with an oxide phase. For the subsequently annealed microcrystalline electrode whose major phase was Ni₃Sn₄, the reversible capacity was relatively low but exhibited very good cyclic properties. By optimising the high capacity of the nanocrystalline structure and the good cycling properties of the Ni₃Sn₄ phase, this new anode material will lead to further improvements in the performance of Li-ion batteries.

Different types of cobalt oxide were investigated as lithium-storage materials in Li-ion cells. Nanosize Co₃O₄ and CoO powders were prepared by decomposing organo-cobalt compounds at low temperature. Electrochemical testing demonstrates that cobalt oxide electrodes have the capability to reversibly react with lithium to a certain extent. LT(low temperature)-Co₃O₄ and CoO show good capacity retention on charge-discharge cycling, which is promising for their use as anode materials in Li-ion cells. Results from ex situ XRD studies on the Co₃O₄ electrode verified that Li₂O and Co, the products of lithiation, are nano-particles. The electrochemical properties of cobalt oxides are dependent on the crystallinity, morphology and particle size of the oxides. Optimisation of the microstructure of cobalt oxides can improve their electrochemical performance.

The structure and electrochemistry of LiCr_xMn_{1-x}O₂ as a cathode material for lithium-ion batteries have been investigated. M-LiCr_xMn_{1-x}O₂ solid solution was synthesized by a solid-state reaction method. For Cr substitution, x = 0.05 is sufficient to obtain a >90% layered phase, and the purity of the materials increases with an increase in Cr substitution. During electrochemical charge/discharge cycling, the LiCr_xMn_{1-x}O₂ compounds develop two voltage plateaus at 4 and 3 V vs. a lithium anode, suggesting spinel-like cation ordering. However, the resulting materials show excellent cycle ability and a high reversible capacity when cycled over both voltage plateaus, unlike the LiMn₂O₄ spinels. A specific composition (LiCr_{0.15}Mn_{0.85}O₂) exhibited >160 mA/g reversible capacity at the c/5 rate. Cr doping decreased the capacity fade rate for LiMnO₂, and the capacity fade rate decreases with an increase in Cr substitution. To remove the Li₂MnO₃ from samples, the samples were treated with H₂SO₄ for 24 h. AC impedance spectra show that the charge transfer resistance is reduced by the H₂SO₄ treatment process, possible reason may be that H₂SO₄ can lead Li₂O out of Li₂MnO₃, or that Li₂MnO₃ in the samples could be transformed to active LiMnO₂. From XRD patterns, it can also be seen that H₂SO₄ has transformed a small amount of LiMnO₂ to LiMn₂O₄. However the total effect of H₂SO₄ treatment has been to improve the electrochemical performance of the materials and, therefore, it could be a good method to remove nonactive materials from samples.

4 papers from this project were published in 2002.

Fabrication and Characterisation Diboride Superconducting Wires

Funded:	2002	2003	2004
Project ID:	P0219629		
Chief Investigator:	S.X. Dou, X.L. Wang, M. Ionescu		
Partner Investigator:	M. Sumption		
Industry partners:	Hyper Tech Research Inc. OH USA, Alphatech International Ltd. Sydney		

The aim of the proposed project is to investigate the fabricability and properties of MgB₂ superconducting wires using a number of processing techniques established in previous low temperature and high temperature superconductors. The expected outcome is to have a MgB₂ conductor that has a higher performance in magnetic fields than niobium-titanium (NbTi) alloy, a higher operating temperature (up to 20K), and a lower cost than current commercial NbTi wire.

Task-1: Copper, silver and iron have been studied as sheath materials for manufacturing metal sheathed tapes. We found the mechanical deformation rate has different effects on the J_c performance by using different sheath materials. By increasing the deformation rate the critical current density was improved by about an order of magnitude for the copper-sheathed tapes, while the critical current density of the iron-sheathed tapes remained constant.

Task-2: MgB₂ polycrystalline samples were fabricated by in-situ reaction using different grain sizes of SiC and different doping levels. Grain sizes of the SiC precursors have a strong effect on the critical current density and its field dependence. It was found that very fine SiC powder plays an important role in the reaction between Mg+B and SiC. Significant enhancements of J_c and H_{irr} were found for all the SiC doped MgB₂ with addition level up to 15 wt%. A J_c value as high as 20,000 A/cm² in 10 Tesla and 5 K was achieved for the sample doped with 10 wt% SiC having grain sizes of 20 nm.

Task-3: We have investigated the effects of sintering time and temperature on the formation and critical current densities of Fe-clad MgB₂ wires. In contrast to the common practice of sintering for several hours, the present results show that there is no need for prolonged heat treatment in the fabrication of Fe-clad MgB₂ wires. A total time in the furnace of several minutes is more than enough to form nearly pure MgB₂ with high performance characteristics. These findings substantially simplify the fabrication process, making it possible to have a continuous process for fabrication and reducing the costs for large-scale production of MgB₂ wires.

Task-4: We have made solenoid coils up to 100 turns with Cu-sheathed MgB₂ wires using a wound-reaction in-situ technique. Our results demonstrate that the decrease in transport J_c with increasing length of MgB₂ wires is insignificant. Solenoid coils with diameters as small as 10 mm can be readily fabricated using a wound-reaction in-situ technique. The J_c of coils is essentially the same as in the form of straight wires. A J_c of 133,000 A/cm² and 125,000 A/cm² at 4K and self field has been achieved for small coil wound using Cu-sheathed tape and Cu-sheathed wire, respectively. These results indicate that MgB₂ wires have a great potential for large scale applications.

An APAI was awarded to Yue Zhao in October 2002 and he is working on the coated MgB₂ project. His progress is satisfactory.

S. Soltanian, X.L. Wang, A.H. Li, E.W. Collings, M.D. Sumption, E. Lee, H.K. Liu and S.X. Dou "Fabrication and critical current density in 16-filament stainless steel/Fe/MgB₂ square wire" *Solid State Communs.* **124** 59-62 (2002)

S. Zhou, A.V. Pan, M. Ionescu, H.K. Liu and S.X. Dou "Influence of Ag, Cu and Fe sheaths on MgB₂ superconducting tapes" *Supercond. Sci. Technol.* **15**, 236-240 (2002)

S. Zhou, A.V. Pan, H.K. Liu and S.X. Dou "Single-and multi-filamentary Fe-sheathed MgB₂ wires" *Physica C* **382** 349-354 (2002)

Investigation of nano-materials for use in lithium rechargeable batteries

Funded:	2002	2003	2004
Project ID:	LP0219309		
Chief Investigator:	H.K. Liu, S. Zhong		
Partner Investigator:	J.H. Ahn		
Industry Partners:	Sons of Gwalia, OM Group, Lexel Battery Ltd.		

The Project was started in October 2002 as the Industry Partner Jindalee Ltd. was replaced by Sons of Gwalia Ltd. in April 2002. QNI Ltd was replaced by the OM Group and Lexel Battery Ltd. in October 2002. The research collaboration agreement between the University of Wollongong and the industry partners was made on 30th October 2002.

In 2002 we have studied a potential use of aluminium based intermetallic alloys. The electrochemical properties of Fe₂Al₅ as anode materials in Li-ion cells were systematically tested. Fe₂Al₅ was prepared by arc melting the constituent elements, crushing to a suitable size and then ball milling. The highest discharge capacity (485 mAh/g) observed was as a result of ball milling for 10,000 minutes which is consistent with the theoretical capacity for formation of AlLi (543 mAh/g). Cyclic voltammetry and differential capacity plots however do not offer conclusive evidence of the formation of AlLi. Both the charge and the discharge capacities improved with increasing milling time but the cycle life remained poor. Removal of lithium from the structure was difficult with charge capacities being quite low. The first charge capacities for instance were in the range of 20-40% of the first discharge capacity.

The electrochemical performance of Fe₂Al₅ is improved significantly via ball milling but not to a sufficient degree as yet to be a viable replacement for existing anode materials. If the difficulty in removing lithium from the structure can be overcome Fe₂Al₅ may be a suitable anode material for lithium-ion batteries. Altering the microstructure by further milling and/or annealing may be able to improve the electrochemical performance of the alloy. Crystalline Fe₂Al₅ electrodes that contained no conductive additive clearly demonstrated that some interaction with lithium occurs, with the ball milled (500 minutes) electrode having a reversible capacity of approximately 20 mAh/g. This is despite the crystalline size of 41 nm being much greater than the 10 nm of previous aluminium intermetallics investigated and reported as inactive.

M.J. Lindsay, G.X. Wang, H.K. Liu, "Al-based anode materials for Li-ion batteries", Proceedings of "International meeting on Lithium Batteries", accepted for publication (2003)

Developing new cathode materials for Li-ion batteries using Australian mineral resources

Funded:	2002	2003	2004
Project ID:	LP0214179		
Chief Investigator:	S.X. Dou		
Assoc. Investigator:	G.X. Wang, J.Y. Lee, S.J. Kennedy		
Industry Partners:	Sons of Gwalia, OM Group		

The proposal will bring together expertise in materials processing, structure characterisation and electrochemistry to carry out collaborative research on cathode materials for lithium ion batteries. The major objective of this proposed project is to develop technologies for preparing advanced cathode materials used in rechargeable lithium-ion batteries. Due the merge of the BHP and Billiton groups, one of the industry partners, QNI of Billiton, withdrew from this linkage project after the ARC approved the grant. The final signing of the contract with the Sons of Gwalia Ltd and OMG Ltd was delayed to the end of October 2002. So far we have carried out the following work.

We have synthesised layered-structure LiMN_{1-x}Cr_xO₂ by the Pechini method and characterised the material as a cathode for rechargeable Li/LiMNO₂ cells. The cathode material showed improved capacity and long cycle life. We have developed a spray solution technique for ultra-fast preparation of a quality LiFePO₄ material. The method features fast and easy synthesis of a single-phase product with a homogeneous crystal size distribution.

Special attention was paid to preparation of fine crystal sized materials, which possesses higher capacity. The method includes preparation of the initial water-based HNO₃ solution (5 wt % nitric acid) of Li₂CO₃, FeC₂O₄.2H₂O and NH₄H₂PO₄ in the corresponding stoichiometric ratio Li:Fe:P = 1:1:1. The solution is sprayed in a heated spray reactor at temperatures in the range of 400-650°C. The obtained precursor is finally sintered under Ar at temperatures in the range of 600-850°C for 2-9 hours. The overall process can take less than 4 hours. Systematic XRD analysis revealed that the final powder is a single phase LiFePO₄ product. The SEM photos reveal a good crystallinity and homogeneous microstructure of the samples despite the short sintering time.

We have applied the spray pyrolysis technique to in-situ fabrication of nano-featured spherical oxide materials. Two different nano-featured single-phase materials for battery use, namely LiCoO₂ and PbO, were successfully prepared in spherical form. The diameters of the spheres are in the range of a few microns, generally 1-10 microns, and there is a narrow Gaussian particle size distribution. The diameter size can be controlled by the size of the spray nozzle and the concentration of the solution. The spherical agglomerates appear to consist of nano-particles, each one with dimensions of 20-50 nm. The specific surface areas of these materials are several times higher than for the corresponding commercially available powders. The stoichiometry of the LiCoO₂ powders thus obtained was controlled by the ICP technique in order to achieve the desired Li:Co = 1:1 ratio in the sintered materials. The materials prepared by the spray pyrolysis technique appear to be promising for battery use.

S. Bewlay was awarded the APAI in March 2002. He has made significant progress on the fabrication of cathode materials using the spray pyrolysis technique.

Z.P. Guo, S. Zhong, G.X. Wang, G. Walter, H.K. Liu and S.X. Dou, "Synthesis of layered-structure LiMN_{1-x}Cr_xO₂ by the Pechini method and characterisation as a cathode for rechargeable Li/LiMNO₂ cells" *J. Electrochem. Scty* **149**, **6**, A792-A795 (2002)

K. Konstantinov, J. Wang, S. Bewlay, G. X. Wang, H. K. Liu, S. X. Dou and J. -H. Ahn, "Spray Pyrolysis Technique for Fabrication of Nano-sized Spherical Agglomerated Oxide Powders for Batteries", *J. Nanosci. Technol.* in press (2003)

Thermionic cooling for domestic refrigeration

Funded:	2000	2001	2002
Project ID:	C00001867		
Chief Investigator:	R.A. Lewis, C. Zhang		
Industry Partner:	Email Limited		
Postgrad. Students:	Ben Lough		

We carried out the following research in 2002.

- (i) Further development of new numerical programs to simulate performance of single and double layer structures. Numerical results for thermal efficiency for various different structures were obtained.
- (ii) Design and fabrication of the second generation elementary structure for domestic refrigeration.
- (iii) We performed electrical measurement to determine I-V characteristics of the second generation structure. The asymmetric contact resistance at the top and bottom metal-semiconductor interface were accurately determined.
- (iv) We performed theoretical analysis on the mechanism of energy transport in multilayer systems based on homo- and heterostructures. Our results reveal that the electron thermal distribution plays a significant role in the thermionic emission.
- (v) We developed simulation codes on the thermal transport to study the optimal operation condition of various structures.

Related publications:

- [1] B. Lough, S. P. Lee, R. A. Lewis, C. Zhang, *Numerical calculation of thermionic cooling efficiency in a double barrier semiconductor heterostructure*, *Physica E* **11**, 287 (2001).
- [2] B. Lough, S. P. Lee, R. A. Lewis, and C. Zhang, *Electronic thermal transport and thermionic cooling in semiconductor multi-quantum-well structures*, *Comp. Phys. Commun.* **142**, 274 (2001).

- [3] S. P. Lee, B. Lough, R. A. Lewis, C. Zhang, *Thermionic cooling of optoelectronic and microelectronic devices*, IEEE Proceedings of Optoelectronic and Microelectronic Materials and Devices, (IEEE Catalog No. 00EX4666C, 2002), page 415
- [4] B. Lough, S. P. Lee, Z. Dou, R. A. Lewis, C. Zhang, *Thermal and optical determination of temperature on a multilayer thermionic device*, Physica E (2003, in press)
- [5] R. A. Lewis and B. C. Lough, *Spectroscopic determination of valence band parameters of InP*, 27th Annual Condensed Matter and Materials Meeting, (Wagga, Feb. 2003)

Thermionic cooling for domestic refrigeration , Project ID: C00106566

Funded:	2001	2002	2003
Chief Investigator:	R.A. Lewis, C. Zhang		
Industry Partner:	Email Limited		
Postgrad. Students:	Zhijian Dou		

In 2002, we performed following tasks.

- We performed thermal and optical measurements on the second generation heterostructure to determine the temporal variation of temperature on various electrodes.
- We designed and fabricated homostructure multilayer devices (several 10-layer devices) based on the simulation result. Electrical and thermal characterization of some devices was performed. The devices show the desired IV curve for electrical transport. Thermal characterization indicated a larger heat backflow than the heterostructure. We are currently performing more thermal and optical measurements to draw quantitative comparison between the homostructures and heterostructures.

Publications:

- [1] B. C. Lough, S. P. Lee, Z. Dou, R. A. Lewis, and C. Zhang, *Thermal and electrical characteristics of a multilayer thermionic device*, IEEE Conf. on Optoelectronic and Microelectronic Materials and Devices, (IEEE publishing, 2003, in press)

4. Reports on IREX Project of International Fellowships in 2002

Composite cathode materials for lithium ion battery using chemical coating technique

Project ID: LX0214959
Funded: 2002
Chief Investigator: S.X. Dou
International Fellow: J.Y. Lee

The aim of this project is to develop new composite cathode materials (LiCoO_2 coated $\text{LiM}_x\text{Mn}_{1-x}\text{O}_2$) using a chemical coating process in order to improve the electrochemical properties such as the cyclic property at elevated temperature and the rate capability. Commercial Li-ion batteries have LiCoO_2 as a cathode material due to its excellent cycle stability and rate capability. However, cobalt is a relatively rare and very expensive transition metal, so attention has been focussed on LiMn_2O_4 with a view to taking advantage of its low cost and environmentally friendly nature compared to LiCoO_2 . The expected outcome is a new cathode material which has high-energy capacity, long cycle life and low cost.

The International Fellowship was awarded to Prof J.Y Lee in early 2002. He planned to take up the fellowship in July last year, however the visa application process caused a long delay until the end of last year. Prof Lee took up the fellowship early this year. The full report can only be provided at the end of July when he finishes this project.

In the last two months we have carried out some preliminary research work on the project. Based on our previous experiences the base line materials, layered LiMn_2O_4 and LiCoO_2 were prepared and characterised separately. The LiCoO_2 -coating solution was prepared by a chemical process and LiCoO_2 coated composite was obtained. For structural analysis of the coated lithium manganese oxide, samples were characterized with x-ray diffraction (XRD) and transmission electron microscopy (TEM). It was found the composite consisted of two phases. Preliminary results show a noticeable improvement in the rate capacity of the LiMn_2O_4 after surface coating with LiCoO_2 . The coating plays an important role in improvement of activation processes for the Li absorption and desorption. Further cell tests on capacity and cycle life are underway.

Prof Lee gave a series of five lectures on the proposed topics to our staff and postgraduate students during this period. The lecture series will continue. We found these lectures to be very informative and educational for our staff and postgraduate students, as Prof Lee is a distinguished professor and internationally renowned expert in energy storage research.

A paper was prepared for submission:

S.C. Park, K.T. Kim, J.Y. Lee, H.K. Liu and S.X. Dou, "Improvement of thermal decomposition property of cell using LiCoO_2 by surface coating with LMn_2O_4 ".

Investigation of a series of metallic substrate materials suitable for developing long Y-Ba-Cu-O superconductors

Funded:	2002	2003	2004
Project ID:	LX0211084		
Australian Investigator:	H.K. Liu		
Partner Investigator:	D.L. Shi		

In 2002, the researchers from the University of Wollongong (UoW) and the University of Cincinnati (UoC) together have studied the buffer layer and textured metal. Suitable substrate materials have been chosen, based on the time and temperature relationship. UoC provided the non-fluorine sol-gel solution to the UoW, while the PhD student at the UoW has grown $\text{YBa}_2\text{Cu}_3\text{O}_y$ films on polycrystalline Ag and single crystalline yttrium-stabilized zirconia (YSZ), using the non-fluorine sol-gel and a spin coating. A paper entitled "Microstructures and phase evolution in nano-crystalline $\text{YbB}_2\text{Cu}_3\text{O}_y$ films grown on Ag and YSZ substrates via a non-fluorine sol-gel route" by A.H. Li*, M. Ionescu*, H.K. Liu* and D.L. Shi** (*Institute for Superconducting and Electronic Materials, University of Wollongong, NSW 2522 Australia, ** Department of Materials Science and Engineering, University of Cincinnati, 497 Rhodes Hall, Cincinnati, OH 45221-0012, USA) was presented at an international conference (ISMANAM) and the abstract appeared in Program & Abstracts, International Symposium on Metastable, Mechanically Alloyed and Nanocrystalline Materials, page 58, Seoul, South Korea, 8th ~ 12th September, 2002.

The micro-morphologies and phase formation were investigated by optical microscope, scanning electron microscope and X-ray diffraction. It was found that the thick films deposited on YSZ by spin-coating revealed serious microcracks with long crack distances after sintering at high temperatures. However, for films grown on Ag substrates, the microcracks were reduced significantly after sintering. It is proposed that the surface roughness of the substrates is one of the reasons responsible. A novel treatment involving high temperature sintering above the decomposition temperature of the sol-gel was used to totally eliminate the microcracks. The phase formation was also studied over a wide temperature range from 700 up to 900°C in air and a pure oxygen atmosphere. It was observed that a single phase can be formed on Ag substrate at 800 °C. However, the films grown on YSZ reacted with YSZ and formed BaZrO_2 .

The full refereed paper has been accepted for publication in the Journal of metastable and nanocrystalline materials by publisher - TTP Trans Tech Publication Ltd, Switzerland.

Investigation of Novel Metal Nickel Hydride Electrode for Rechargeable Batteries

Funded:	2001	2002
Project ID:	X00106668,	
Australian Investigator:	S.X. Dou	
International Fellow:	A.H. Ahn	

Prof Ahn was appointed an international research fellow at the Institute of Superconducting and Electronic Materials, University of Wollongong in July, 2001. His work during this period focused on the development of new nanocrystalline materials for energy storage applications.

A. Preparation of Mg-based nanocrystalline metal hydrides for Ni-MH secondary batteries : Mg-based alloys such as Mg₂Ni are one of the most promising metal hydride alloys due to their high theoretical capacity for hydrogen storage. However, the hydrogen absorption can occur at high temperatures above 300°C, requiring tedious activation processes. To overcome this problem, I have employed two approaches: 1)-high-energy ball milling to produce nanocrystalline structures which can increase the reactivity and activity of the alloys, and 2)-the compositional optimization of Mg₂Ni by addition of carbon or calcium as an oxygen getter. Several nanocrystalline Mg₂Ni alloys have already prepared using high-energy ball milling. The hydrogen storage properties as negative electrodes in Ni-MH cell will soon be examined after the arrival of the reference electrodes.

B. Development of nanocrystalline alloys for anode materials in Li-ion batteries: Although graphite has been successfully used as an anode material in commercial Li-ion batteries, its theoretical capacity is only one tenth of that of lithium metal. There is thus a strong need for new alternative anode materials replacing graphite. For this purpose, I have prepared several new nanocrystalline alloys and nanocomposites (Ni-Sn, TiC-Sn, TiC-SnO, Ni-Sn-SiO₂, Sn-SiO₂.) and examined their electrochemical properties. The preliminary results show that these nanocrystalline alloys exhibit much higher initial discharge-charge capacities than graphite. The main drawback of these materials is a rapid decline of capacities on cycling. An effort is now being made to resolve this problem. Some related results have been submitted to scientific journals.

C. Synthesis of carbon nanotubes for applications as anode materials in Ni-MH and Li-ion batteries: Carbon nanotubes have recently attracted much attention among scientists for their exceptional properties and possible applications in various fields. Considering its potential importance in hydrogen and Li-ion storage application, the ISEM plans to study this field. As a part of the first step of this study, I have examined the synthesis conditions using chemical vapour deposition. The main objectives were to establish easy and simple methods which are not only suitable for mass production but also capable of producing high quality nanotubes, such as well-aligned tube with a uniform size distribution. The first results show that the optimal synthesis conditions are strongly affected by the catalytic precursors of the transition metal as well as by the nature of substrate materials. Some preliminary results on lithium storage properties were submitted to scientific journals.

Some results of the above-mentioned experiments have been already submitted to scientific journals and accepted for the publication.

J-H Ahn, GX Wang, M Lindsay, H K Liu and S X Dou: "Lithium Storage Properties of Ball Milled Ni-57 mass % Sn Alloy", *Materials Transactions*, Vol 43, *JIM*, No.1 (2002) 1

J-H. Ahn, G.X. Wang, H.K. Liu and S.X. Dou, "Li Storage Properties of Carbon Nanotubes Prepared by Chemical Vapour Deposition", *J. of Metastable and Nanocrystalline Mater.* (accepted on Dec 17, 2001)

G.X. Wang, J-H Ahn, J Yao, M Lindsay, H.K. Liu and S.X. Dou, "Characterisation of Multiwall Carbon Nanotubes as Lithium Storage Host", submitted to *J. of Power Sources*

G.X. Wang, J-H Ahn, J Yao, M Lindsay, H.K. Liu and S.X. Dou, "Nanosize Cobalt Oxides as Anode Materials for Lithium-ion Batteries", submitted to *J. of Alloys and Compounds*

Phase equilibrium diagram of Ag/Bi₂O₃-PbO-SrO-CaO-CuO system

Funded:	2001	2002
Project ID:	X00106484	
Australian Investigator:	H.K. Liu	
International Fellow:	P. Majewski (Germany)	

Experimental studies were carried out during the visiting period of 21/5/2001 – 31/8/2001 and 28/6/2002 – 7/9/2002 by Dr. Peter Majewski at the Institute of Superconducting and Electronic Materials of the University of Wollongong and at the Max-Planck-Institute for Metals Research, Stuttgart, Germany, during the period between the stays in Wollongong. Prof. Liu, Dr. X.L. Wang and Prof. Majewski together received an ARC Discovery Near Miss Grant in 2002.

The discovery of the high-temperature superconducting phases in the Bi-Sr-Ca-Cu-O system (Bi_{2+x}Sr_{2-y}Ca_{1+y}Cu₂O_{8+d}, 2212 phase, $T_c \leq 95$ K and Bi_{2+x}Sr_{2-y}Ca_{2+y}Cu₃O_{10+d}, 2223 phase, $T_c \leq 110$ K) has stimulated worldwide research activities aimed at understanding and controlling these exciting materials. One of the technologically most interesting applications of the materials is wires and tapes which can be used for the construction of transformers, generators, and high electric current cables. Today, tapes are prepared using 2223 precursor. Powders are filled into silver tubes which provide the sheath of the ceramic. The tubes are drawn, rolled, and finally sintered in order to form the superconductor. This normally applied solid state processing causes a high amount of pores within the ceramic superconductor which reduces the critical current density. In the frame of the project a new preparation method is tested which is based on the melt processing of the superconductor within the silver sheath. Melt processing provides much denser ceramic material within the wires and tapes, and therefore, could enhance the critical current density.

Powders with the chemical composition Bi_{2.4}Sr_{1.9}Ca_{2.1}Cu_{3.1}O_{10+x} were ball milled and calcined at 750, 790, 820 and 840°C for 12 h. After this heat treatment the powders consist of mainly Ca enriched Bi₂Sr₂CaCu₂O₈, Ca₂CuO₃ and CuO. The powders were then filled into silver crucibles and mechanically densified. The final annealing was performed at different temperatures between 860 and 870°C. Differential thermal analysis was applied in order to define the temperature of peritectic melting. The samples were quenched in air and characterized using X-ray powder diffraction and Scanning Electron Microscopy with Energy Dispersive Spectrometer.

The results reveal that melt processing of Bi-2223 is possible. The obtained samples consist of high amounts of Bi-2223 beside melt and CuO. Although the results are very promising with respect to the development of an alternative processing of Bi-2223 tapes, several advantages and disadvantages of the method have to be considered:

Advantages: (1) The reduction of the annealing time of Bi-2223 melt processing decreases the costs of processing, even considering the slightly enhanced annealing temperature of 864°C compared to the oxide powder in tube process (800 – 830°C). (2) The process can be performed in air which reduces the costs for special gases used for the oxide powder in tube (OPIT) process. (3) Melt processing provides an increase in density of the final material and large crystals of Bi-2223 compared to OPIT which is known to increase the critical current density. (4) No need of lead reduces the costs for avoiding environmental contamination, health problem of the persons involved in the process.

Disadvantages: (1) The very small temperature range (862-864 °C) for optimum processing conditions may cause technical difficulties and enhanced the costs for high accurate furnace controls when up scaling of the process to industrial standard. (2) The performance of melt-processed tapes are not specified yet.

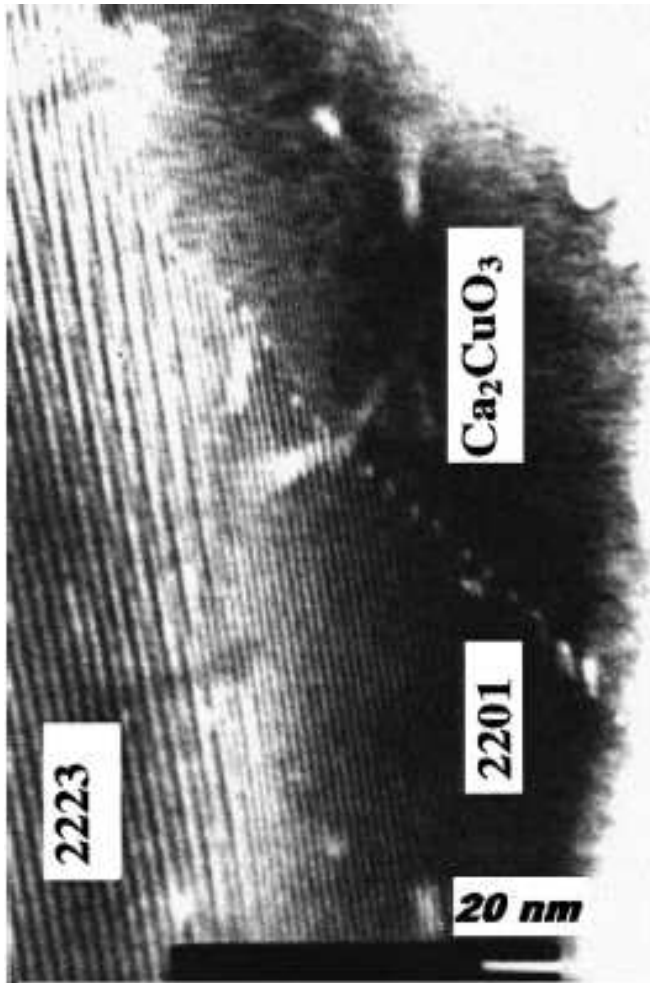
Summarizing the results, it is emphasized that the obtained melt processing of Bi-2223 may offer significant advantages. However, it is inevitable to prepare melt processed Bi-2223 tapes in order to specify their performance and performance over cost ratio for comparison to standard OPIT Bi-2223 tapes.

Selected Abstracts

High Temperature Superconductivity Group

Transmission electron microscopy evidence for phase transformation from $\text{Bi}_2\text{Sr}_2\text{CuO}_6$ to $\text{Bi}_2\text{Sr}_2\text{Ca}_2\text{Cu}_3\text{O}_{10}$, App. Phys. Lett. **81**, 4, 688-690 (2002)

W. M. Chen, G. Li, S. S. Jiang, H. Y. Ling, P. Yao, M. J. Qin,b, H. K. Liu, and S. X. Dou



The growth mechanism of the Bi-2223 phase was studied using multifilamentary Ag/Bi-2223 tapes manufactured by the powder-in-tube method. X-ray powder diffraction was performed to analyze the developments of Bi-2201, Bi-2212, and Bi-2223 phases during sintering periods at high temperatures. Transmission electron microscopy (TEM) was used to investigate the growth mechanism of the 2223 phase. TEM images indicated that 2201 and Ca_2CuO_3 crystals come together to form platelets of 2223. The structural phase transformation established a structural frame of the 2223 crystal. There were some vacant defects retaining in the established 2223 crystal cells at copper and oxygen sites after the phase transformation, and the Cu/O compound at high temperatures would diffuse into 2223 cells and occupy the corresponding vacancies to complete the 2223 crystal structure. The present work provides an evidence for growing the 2223 phase from the 2201 phase and Ca_2CuO_3 in the samples studied.

FIG. 3. This is an image of a transition region with high brightness, starting from the upper right and extending down towards the lower middle of Fig. 2. In the upper right of the image, Ca_2CuO_3 and 2201 platelets are joining together, with the pieces of the Ca_2CuO_3 platelet diffusing into broken 2201 platelets. These eventually react completely to form the 2223 platelets as can be seen in the bright area at the lower middle of the image.

Effect Of Various Mechanical Deformation Techniques On Pinning Force Densities In Ag/Bi-2223 Tapes, Advances In Cryogenic Engineering: Proc. of the International Cryogenic Materials Conference **48**, 748-754 (2002)

W. M. Chen, H. K. Liu, X. K. Fu, Y. C. Guo, D. Q. Shi and S. X. Dou

Ag/Bi-2223 tapes were fabricated using the Powder-In-Tube method, involving intermediate deformation techniques of sandwich rolling (SR), pressing (P) and normal rolling (NR). Magnetic field B dependence of J_c was measured. Depending on the relationship between J_c and B , the irreversible magnetic field B_{irr} was determined and pinning force density F was calculated. The experimental results showed that self-field- J_c was linear with the relative density for SR-, P- and NR-tapes. Our experimental results support that NR-, P-, and SR-tapes have a same sort of pinning center and the intermediate deformation processing cannot change property of pinning centers, but can effect the pinning force strength. Our experimental results also support

that sandwich rolling is the best technique for fabricating Ag/Bi-2223 tapes. Proceedings of the International Cryogenic Materials Conference - /CMC, Vol. 48, edited by B. Balachandran et al. © 2002 American Institute of Physics 0-7354-0060-1/02/\$19.00 748

Substitution-induced pinning in MgB₂ superconductor doped with SiC nano-particles, Supercond. Sci. & Tech. **15**, 1587-1591 (2002)

S.X. Dou, A.V. Pan, S. Zhou, M. Ionescu, H.K. Liu and P. R. Munroe

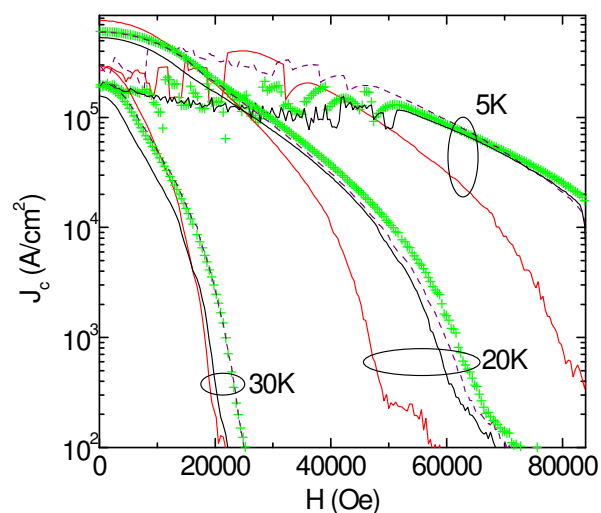
By doping MgB₂ superconductor with SiC nano-particles, we have successfully introduced pinning sites directly into the crystal lattice of MgB₂ grains (intra-grain pinning). It became possible due to the combination of counter-balanced Si and C co-substitution for B, leading to a large number of intra-granular dislocations and the dispersed nano-size impurities induced by the substitution. The magnetic field dependence of the critical current density was significantly improved in a wide temperature range, whereas the transition temperature in the sample MgB₂(SiC)_x having x=0.34, the highest doping level prepared, dropped only by 2.6K.

Enhancement of the critical current density and flux pinning of MgB₂ superconductor by nanoparticle SiC doping Appl. Phys. Lett. **81** 3419 (2002).

S.X. Dou, S. Soltanian, J. Horvat, X.L. Wang, S.H. Zhou, M. Ionescu, H.K. Liu, P. Munroe and M. Tomsic

Doping of MgB₂ by nano-SiC and its potential for the improvement of flux pinning were studied for MgB_{2-x}(SiC)_{x/2} with x = 0, 0.2 and 0.3 and for 10wt% nano-SiC doped MgB₂ samples. Co-substitution of B by Si and C counterbalanced the effects of single-element doping, decreasing T_c by only 1.5K, introducing intra-grain pinning centres effective at high fields and temperatures, and significantly enhancing J_c and H_{irr}. Compared to the un-doped sample, J_c for the 10wt% doped sample increased by a factor of 32 at 5K and 8T, 42 at 20K and 5T, and 14 at 30K and 2T.

At 20K and 2T, the J_c for the doped sample was 2.4x10⁵A/cm², which is comparable to J_c values for the best Ag/Bi-2223 tapes. At 20K and 4T, J_c was twice as high as for the best MgB₂ thin films and an order of magnitude higher than for the best Fe/MgB₂ tapes. The magnetic J_c is consistent with the transport J_c which remains at 20,000A/cm² even at 10T and 5K for the doped sample, an order of magnitude higher than the undoped one. Because of such high performance, it is anticipated that the future MgB₂ conductors will be made using a formula of MgB_xSi_yC_z instead of pure MgB₂.



The effect of hydrogenation on the superconducting transition temperature of MgB₂, Physica C **382** 213-216 (2002)

V. V. Flambaum, G. A. Stewart, G. J. Russell, J. Horvat and S. X. Dou,

Hydrogenation of commercial MgB₂ powder (superconducting transition temperature 38.2 K) at temperatures ≥ 600 °C and hydrogen pressures up to 10 bar has led to an increase in T_c, as determined by ac susceptibility measurements. Applied dc fields reduced the transition temperature by a slightly larger value than that for the

pure powder. Heating the MgB₂ powder for 2 h at 600 °C in 10 bar of either helium or argon gas has also lead to an increase in the transition temperature. © 2003 Elsevier Science B.V. All rights reserved.

Far-infrared reflection and transmission of La_{1-x}Ca_xMnO₃, J. of Alloys and Compounds **347**, 1-2, 314-318 (2002)

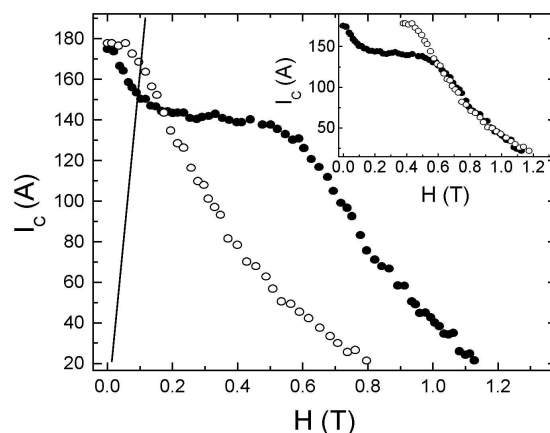
F.Gao, R. A. Lewis, X. L. Wang and S. X. Dou

Colossal magnetoresistance compounds of composition La_{1-x}Ca_xMnO₃ have been investigated by far-infrared spectroscopy. In contrast to earlier work, which has concentrated on reflection data for La_{2/3}Ca_{1/3}MnO₃, the present work includes transmission data and covers the Ca substitution range 0 ≤ x ≤ 0.5. The spectra are found to be sensitive to processing variables such as precursor composition, processing route, and annealing temperature. The (La,Ca)–(MnO₃) vibration (~200 cm⁻¹) decreases in absorption and increases in energy with x. The O–Mn–O bending mode (~400 cm⁻¹) behaves likewise. The Mn–O stretching mode (~600 cm⁻¹) decreases in absorption with increasing Ca, but, in contrast to the other modes, initially moves to lower energies as the Ca content increases.

Improvement of critical current in MgB₂ superconducting wires by a ferromagnetic sheath, Appl. Phys.Lett. **80** 829-831 (2002)

J. Horvat, X. L. Wang, S. Soltanian and S. X. Dou

Transport critical current (I_c) was measured for Fe-sheathed MgB₂ round wires. A critical current density of 5.3 x 10⁴ A/cm² was obtained at 32K. Strong magnetic shielding by the iron sheath was observed, resulting in a decrease in I_c by only 15% in a field of 0.6T at 32K. In addition to shielding, interaction between the iron sheath and the superconductor resulted in a constant I_c between 0.2 and 0.6T. This was well beyond the maximum field for effective shielding of 0.2T. This effect can be used to substantially improve the field performance of MgB₂/Fe wires at fields at least 3 times higher than the range allowed by mere magnetic shielding by the iron sheath. The dependence of I_c on the angle between field and current showed that the transport current does not flow straight across the wire, but meanders between the grains.



Growth of MgB₂ thin films by pulsed laser deposition, Invited Presentation at the International Conference on Advanced Materials, organised by the European Materials Society (E-MRS), 18-21 June, 2002, in Strasbourg, France

M. Ionescu

The recent discovery of metallic-like superconductivity in bulk MgB₂ material, opened a new class of possible applications in current transport, magnetic field devices and electronic devices. Fabrication of thin films in-situ is essential in order to explore the device applications of this material, and in spite of a few reports, this still remains a challenge. The main reasons for this are the high vapour pressure of Mg even at low temperatures, and the high susceptibility of Mg to oxidation. A number of c-axis oriented MgB₂ films were grown on Al₂O₃-R cut, and the stoichiometry of the films was measured by ICP as a function of deposition pressure and laser fluency. It was found that the relative concentration of Mg on the substrate varies considerably with pressure and laser fluency. A relative concentration of around 53 at% Mg, which is necessary in order to form

stoichiometric MgB_2 phase, can be obtained only in a narrow range of deposition pressures and laser fluencies. The films obtained under these conditions were characterised by X-ray diffraction and magnetic moment in applied fields up to 9T.

The crystal structure and magnetic properties of the 1-dimensional dihalide-bridged polymers dichlorobis (thiazole) cobalt (II) and dibromobis (thiazole)-cobalt (II), J. Phys. Chem. Solids **63**657-663 (2002)

M. James and J. Horvat

The isostructural polymeric compounds $\text{Co}(\text{thiazole})_2\text{X}_2$ ($\text{X}=\text{Cl}$ (**1**), Br (**2**)) have been synthesised by the addition of thiazole to an ethanolic solution of the corresponding anhydrous cobalt halide. Powder X-ray and neutron diffraction measurements were used for structural determination. The structures were determined using powder neutron diffraction data and Rietveld techniques: (**1**) $C2/c$, $a=17.806(2)$ Å, $b=3.6806(6)$ Å, $c=14.807(3)$ Å, $\beta=94.78(1)^\circ$, $V=967.1(3)$ Å³, $Z=4$; (**2**) $C2/c$, $a=18.079(3)$ Å, $b=3.8138(8)$ Å, $c=15.022(4)$ Å, $\beta=92.71(1)^\circ$, $V=1034.6(4)$ Å³, $Z=4$. Each linear polymer chain is composed of pseudo-octahedral, high-spin Co^{2+} centres, doubly linked by halide bridges. Magnetisation measurements of **1** and **2** at 5 K between 0 and 10 kG reveals a metamagnetic transition between antiferromagnetic and ferromagnetic states. Low temperature susceptibility data have been fitted to a one-dimensional Ising model with a mean field correction and were found to be anisotropic with ferromagnetic intrachain interactions along the b -axis and weaker antiferromagnetic interchain interactions.

Intrinsic nanostructural domains: Possible origin of weaklinkless superconductivity in the quenched reaction product of Mg and amorphous B, App. Phys. Lett. **81**, **5**, 874-876 (2002).

S. Li, O. Prabhakar, T. T. Tan, and C. Q. Sun, X. L. Wang, S. Soltanian, J. Horvat, and S. X. Dou

Smooth modulation structure of Mg–B alloy in the quenched reaction product of Mg and amorphous B was studied. It indicates that the MgB_2 formed possibly in spinodal decomposition, thus resulting in MgB_2 nanodomains. It was found that the nanodomains with small angle boundaries of atomic-scale width were distributed within the subgrains that constitute the clusters in MgB_2 grains. This nanostructural characteristic may be intrinsic in the quenched reaction product of Mg and amorphous B. It makes the nanodomain boundaries not act as barriers to the current percolation path, thus exhibiting no weak-link problem in the MgB_2 .

Effect of fission tracks on flux pinning and the resistive transition in neutron irradiated uranium-doped Ag/Bi2223 tapes, Supercond. Sci. Technol. **15** 1596-1599 (2002)

D. Marinaro, J. Horvat, S. X. Dou, I. Kusevic, E. Babic, R. Weinstein and A. Gandini

The extended defects produced by the fission of neutron-irradiated ²³⁵U inclusions in Ag/Bi2223 superconducting tapes act as very effective pinning centres. Substantial improvements in the magnetic field dependence of the critical current densities, J_c , and in the irreversibility line of treated tapes have previously been observed. The magnetoresistance of Ag/Bi2223 tapes treated with the doping and irradiation technique has been measured, and activation energies calculated from the Arrhenius plots. The findings corroborate the previous J_c results, confirming the strong pinning action of the extended columnar defects, particularly in fields aligned along the c -axis of the tapes. © Institute of Physics and IOP Publishing Limited 2003

Magnetic flux distribution in a superconducting core of Bi-2223 tape, the 23rd International Conference on Low Temperature Physics (LT23), August 20-27, 2002, Hiroshima, Japan

A. V. Pan, S. X. Dou, and H. K. Liu

Local magnetic flux distribution in the superconducting core of a Bi-2223 tape is investigated above and below a characteristic field B^* , which is defined by global critical current density J_c measurements. Below this field, J_c as a function of applied magnetic field B_a exhibits a B_a -independent plateau often referred to the single vortex pinning regime. We show that below B^* the flux distribution within the core does not change. Furthermore, the strong B^* (T) dependence is suggested to be due to thermally activated depinning of individual vortices.

3D-2D-like transition above B_{c2} in niobium films, the 23rd International Conference on Low Temperature Physics (LT23), August 20-27, 2002, Hiroshima, Japan.

A. V. Pan, R. Hühne, and P. Esquinazi,

Isotropic superconducting Nb-films thicker than the penetration depth exhibit a magnetically anisotropic structure within the magnetic field range $B_{c2} \leq B_a \leq B_{c3}$, where B_a is the applied field, and B_{c2} and B_{c3} are the upper and surface superconductivity critical fields, respectively. The anisotropic structure of the films consists of three layers: two superconducting surface layers and normal layer in between. Upon tilting the field with respect to the film surface, we have found that surface vortices undergo a 3D-2D-like dimensional crossover. Vortices residing on each of both film surfaces are coupled at fields almost parallel to the surface (3D), and decoupled at larger angles (2D) within the surface superconductivity state.

Calculation of the hysteretic force between a superconductor and a magnet, Phys. Rev. B 66 024516-11 (2002) (2002)

M. J. Qin, G. Li, H. K. Liu, S. X. Dou and E. H. Brandt

The magnetic levitation forces exerted on a superconducting disk (HTS) by a cylindrical permanent magnet (PM) are calculated from first principles for superconductors with finite thickness. The current $j(\rho, z)$ and field $B(\rho, z)$ profiles in the HTS in the non-uniform magnetic field generated by the PM are derived. The levitation force depends nonlinearly on the critical current density j_c and on the thickness of the HTS. The flux creep is described by a current--voltage law $E(j)=E_c(j/j_c)^n$, from which we show that the levitation force depends on the speed at which the PM approaches or recedes from the HTS, which accounts for the experimentally observed force creep phenomenon. The stiffness of the system is derived by calculating minor force loops. The numerical results reproduce many of the features observed in experiments.

Evidence for Vortex-Pinning Induced by Fluctuations in the Transition Temperature of MgB_2 Superconductors Phys. Rev. B 65 132508(2002)

M. J. Qin, X. L. Wang, H. K. Liu, S. X. Dou

The field dependent critical current density $j_c(B)$ of a MgB_2 bulk sample has been obtained using magnetic measurements. The $j_c(B)$ curves at different temperatures demonstrate a crossover from single vortex pinning to small-bundle vortex pinning, when the field is larger than the crossover field B_{sb} . The temperature dependence of $B_{sb}(T)$ is in agreement with a model of randomly distributed weak pinning centers via the spatial fluctuations of the transition temperature (δT_c -pinning), while pinning due to the mean free path fluctuations (δl -pinning) is not observed.

M. J. Qin, H. K. Liu and S. X. Dou

The magnetization hysteresis loop $m(H)$ and ac susceptibility (χ_{ac}) of type-II superconductor strips with geometric barrier have been calculated. The geometric barrier has a prominent effect on the magnetization hysteresis loops and the third harmonic χ_{ac} . The $m(H)$ loop shows hysteretic behavior even for pin-free superconductors, and the third harmonic χ_{ac} shows quite different behaviors for pinning dominated and geometric barrier dominated superconductors, which can be used to experimentally distinguish between different pinning mechanisms in type-II superconductors.

Developments in High Temperature Superconductivity, Annual Report Prog. Chem., Sect. C 98, pp. 323-373 (2002).

T. Silver, A. V. Pan, M. Ionescu, M.J. Qin, and S.X. Dou

The past three years (1997-2001) have seen many exciting developments in high temperature superconductivity, most notably the discovery of the superconducting nature of magnesium boride in 2001 and the amazing critical temperatures of 52 K, then 117 K, achieved in 2000 by hole doping C60 fullerenes through incorporation into a FET transistor. Steady progress has also been made in understanding the recently discovered rutheno-cuprate superconducting ferromagnets. Theoretical work over this period has been focused on understanding the pseudogap in high temperature superconductors and on determining the mechanism behind superconductivity in MgB_2 . Much attention has also been devoted to the rich and complex vortex behaviour found in both the older copper oxide high temperature superconductors and in MgB_2 .

This has also been a period for technological progress. We highlight developments in the field of superconducting tapes and wires, including the considerable success achieved in making high critical current iron-clad MgB_2 tape. Second generation coated conductors have also become an important new field, because they provide a way of overcoming some of the disadvantages of tapes and wires. Small scale devices, such as SQUIDs and microwave filters, have been based on films of high temperature superconductors for some time, but larger scale applications are now coming closer to practical use. Superconducting power transmission cables cooled by liquid nitrogen are now in use in Copenhagen and Detroit.

Study of structure, transport, paramagnetic and ferromagnetic properties of $La_{0.8}Sr_{0.2}Mn_{1-x}Zn_xO_3$ perovskite manganite, *Supercond. Sci. & Technol.* 15(3) (2002) 346,

E. Sotirova, X. L. Wang, J. Horvat, T. Silver, K. Konstantinov, and H. K. Liu

$La_{0.8}Sr_{0.2}Mn_{1-x}Zn_xO_3$ perovskite manganite with $x = 0, 0.01, 0.03, 0.05, 0.1, 0.15, 0.3, 0.5,$ and 0.75 has been prepared by the solid state reaction and investigated by structural, transport, and magnetic measurements. The structural characterisation of the samples has been done by X-ray diffraction (XRD) and scanning electron microscopy (SEM) measurements. The X-ray powder diffraction results indicate a single phase for $0 < x < 0.5$, confirming that zinc is incorporated on the Mn site. The lattice parameters (a, b, c) of this orthorhombic system increase with increasing zinc concentration in the system. According to the SEM images, the grain size of the materials with $x > 0.1$ decreases with increasing zinc doping levels. The transport measurements show that the insulator to metal transition temperature, T_c , decreases with increasing zinc substitution on the Mn site, and the resistivity increases. The T_c variations agree with the magnetic measurement data for $x < 0.3$. The compound changes from ferromagnetic to paramagnetic for $x > 0.3$. The possible mechanism behind the effects of zinc doping into the $La_{0.8}Sr_{0.2}Mn_{1-x}Zn_xO_3$ system involves degradation of the double exchange between $Mn^{3+} - O - Mn^{4+}$ in this compound.

Suppression Of Ac (Hysteretic) Loss By Magnetic Shielding Of MgB₂/Fe Superconductors: The Pseudo-Meissner Effect, Advances In Cryogenic Engineering: Proc. of the International Cryogenic Materials Conference **48**, 824-831 (2002)

M.D. Sumption, E. Lee, E.W. Collings, X.L. Wang, and S.X. Dou

The M - H loops of MgB₂ materials in bulk sintered form, as well as for PIT wire and tape MgB₂/Fe monofilamentary composites, have been measured at various temperatures. The influence of Fe on the M - H loops of the tape and wire are discussed. The normal Fe response is subtracted with the use of M - H loops taken above T_c and the remaining magnetization suppression of the Mg₂ is described in terms of field shunting in the Fe "shield". The level of Fe shielding, both of regions outside of the sample from the MgB₂, as well as the MgB₂ from the outside is discussed, the latter is quantified in terms of a ΔB . Using finite element analysis, ΔB is calculated locally for the tape in both FO and EO field orientations (with the field perpendicular to and along the wide side of the tape, respectively) as well as for the wire sample. It is seen that this ΔB effect can be phenomenologically modelled as a pseudo-Meissner effect. Direct measurements of hysteretic loss vs applied field sweep amplitude, H_m , give a pseudo-Meissner field, H_{PSI} of 2 kOe for the round wire sample in reasonable agreement with calculation. The hysteretic loss above H_{PSI} (and below the penetration field) was found to fit well to an expression proportional to $(H - H_{PSI})^3$. By comparing calculations with and without H_{PSI} it was seen that the Fe sheath significantly reduced the hysteretic loss in externally applied fields for these MgB₂/Fe composites.

Order-disorder transition in Bi_{2.1}Sr_{1.9}CaCu₂O_{8+δ} single crystals doped with Fe and Pb, Phys. Rev. B **65** (2002) 224501

K. K. Uprety, J. Horvat, X. L. Wang, M. Ionescu, H. K. Liu, S. X. Dou, and E. H. Brandt

The magnetic field $H_{dis}(T)$ where an order-disorder transition of the vortex lattice in high- T_c superconductors occurs, is investigated by measurements of the magnetization $M(H)$ in Bi_{2.1}Sr_{1.9}CaCu₂O_{8+δ}(Bi2212) single crystals doped with iron and lead. Comparative studies are made of the temperature dependences of the field $H_{peak}(T)$, where the second peak occurs in $|M(H)|$, and the fields $H_{min}(T)$, and $H_{infl}(T)$ where a minimum and an inflection point occur at the low-field side of this peak. It is proposed that $H_{dis}(T)$ lies close to H_{infl} . In Bi_{2.1}Sr_{1.9}Ca_{1.0}(Cu_{1-y}Fe_y)₂O_{8+δ} single crystals with Fe concentration $y = 0, 0.005, 0.016, \text{ and } 0.022$, a pronounced peak in the derivative $|dM/dH|$ is observed, whose position $H_{infl}(T)$ is independent of temperature T . We relate this peak to the field $H_{dis}(T)$, which separates a weakly elastically disordered vortex lattice from a plastically disordered vortex solid. In heavily Pb-doped single Bi2212 crystals, $H_{infl}(T)$ decreases with increasing T . For the same crystals, a minimum in the normalized relaxation rate $S(H)$ is observed at H_{infl} , indicating two different flux-creep mechanisms above and below that field and two different solid vortex phases. It is argued that the negative slope of $H_{dis}(T)$ in heavily-Pb-doped Bi2212 crystals is related to the enhanced c axis conductivity caused by the Pb sitting between the CuO₂ layers and causing three-dimensional vortex lines, while in Fe-doped Bi2212 crystals the Fe ions sit on the CuO₂ planes and thus do not enhance the coupling between pancake vortices. ©2002 The American Physical Society

Structure and spin glass behaviour in non-metallic Yb₂CoMnO₆ perovskite manganite, J. Mag. Mag. Mater. **246**, 86(2002)

X. L. Wang, M. James, J. Horvat, F. Gao, H.K. Liu, and S.X. Dou

Yb₂CoMnO₆ perovskite manganite was synthesised by solid state reaction. Rietveld refinement of powder X-ray diffraction data indicated that this compound crystallised with a GdFeO₃-type orthorhombic structure containing distorted (Co/Mn)O₆ octahedra ($Pnma$; $a = 5.5593(2) \text{ \AA}$; $b = 7.4154(2) \text{ \AA}$; $c = 5.1825(1) \text{ \AA}$; $V = 213.65(1) \text{ \AA}^3$; $Z = 2$). The dc magnetisation and ac susceptibility were measured at dc fields up to 1 T and an ac field of 0.1 Oe at frequencies of 21, 217, 600 and 2000 Hz over a wide temperature range from 300 K down to 4.2 K. A spin glass ground state was observed at 40 K.

An antiferromagnetic ground state occurs at 25 K which is gradually suppressed by increasing fields. The temperature of the spin glass state was not affected by changing the fields. The spin glass state in $\text{Yb}_2\text{CoMnO}_6$ was observed to arise from a ferromagnetic state and is caused by competition between the ferromagnetic and antiferromagnetic interaction.

Spin glass behaviour in ferromagnetic $\text{La}_2\text{CoMnO}_6$ perovskite manganite, Supercond. Sci. & Technol. 15(3) 427, (2002)

X.L. Wang, M. James, J. Horvat, F. Gao, A.H. Li, H.K. Liu, and S.X. Dou

$\text{La}_2\text{CoMnO}_6$ perovskite manganite was synthesised by solid state reaction. Rietveld refinement of powder X-ray diffraction data indicated that this compound crystallised with an orthorhombic structure containing distorted $(\text{Co/Mn})\text{O}_6$ octahedra ($Pnma$; $a = 5.5 \text{ \AA}$; $b = 7.2 \text{ \AA}$; $c = 5.4 \text{ \AA}$). The dc magnetisation and real part (x') of the ac susceptibility were measured at dc fields up to 1 T and an ac field of 0.1 Oe at frequencies of 21, 217, 600 and 2000 Hz over a wide temperature range from 300 K down to 4.2 K. A ferromagnetic transition was observed at $T_c = 220 \text{ K}$. A spin glass ground state was also determined from the shift of a peak at 220 K in the real part of the ac susceptibility with frequency and slow spin relaxation for $T < T_c$ as indicated by the time-dependence of the remanent magnetisation. The spin glass state arises from a ferromagnetic state and might be caused by competition between the ferromagnetic and antiferromagnetic interaction.

Growth and characterisation of $\text{Bi}_2\text{Sr}_2\text{CaCu}_2\text{O}_y$ thick films on bare polycrystalline Y stabilised ZrO_2 substrate, Supercond. Sci. & Technol. 15(3) 478 (2002)

X L Wang, A H Li, M Ionescu and S X Dou,

$\text{Bi}_2\text{Sr}_2\text{CaCu}_2\text{O}_y$ thick films with a T_{c0} of 88 K have been successfully grown on polycrystalline Y-ZrO₂ substrates using a partial melting technique. It was found that the partial melting temperature, T_m , and the cooling rate strictly control the phase purity and the orientation for the resultant thick films. For the optimum processing, XRD and SEM results reveal that the thick films are single 2212 phase and well c-axis oriented. A T_{c0} as high as 88K is obtained and the critical current density J_c in zero magnetic field is determined to be more than 10^3 A/cm^2 at 60 K and more than $4 \times 10^3 \text{ A/cm}^2$ at 30 K, respectively. The J_c dependence on temperature shows that, near T_c , J_c is proportional to $(1-T/T_c)^n$, with $n \approx 2$, for single 2212 phase, and $n \approx 1.5$ for 2201 phase mixed films, which corresponds to the results of the superconducting-normal-superconducting (SNS) or superconducting-normal-insulating-superconducting (SNIS) models, respectively.

Comparison studies of spiral growth mechanism in $\text{Bi}_2\text{Sr}_2\text{CaCu}_2\text{O}_y$ and $\text{YBa}_2\text{Cu}_3\text{O}_y$ high temperature superconducting single crystals, J. Modern. Phys. Lett. B 16 9-18, (2002)

X.L. Wang, H.K. Liu, and S.X. Dou

The spiral growth mechanisms associated with the growth conditions of $\text{Bi}_2\text{Sr}_2\text{CaCu}_2\text{O}_y$ (Bi-2212) crystals grown at a KCl surface have been studied. The spiral growth mechanisms and the effects of growth conditions on the formation of spirals in $\text{YBa}_2\text{Cu}_3\text{O}_y$ (Y-123) thin films and single crystal have also been studied. Screw dislocation formation mechanism in the Bi2212 is different from that in Y-123. A model for a “vapour” deposition process with discontinuous growth conditions is put forward. It is proposed that spiral growth in Bi-2212 is similar to that in Y-123 thin films produced by Pulsed Laser Deposition. It is concluded that the formation of screw dislocations and discontinuous growth conditions are responsible for the coexistence between spiral and two-dimensional nucleation growth.

The Peak effect in Fe-doped Bi-2212 single crystals, Supercond. Sci. & Technol. 15(3) 356 (2002)

X.L. Wang, H.K. Liu, S.X. Dou, J. Horvat, and G.D. Gu

The peak effect (PE) in Fe-doped $\text{Bi}_{2.1}\text{Sr}_{1.9}\text{Ca}_{1.0}(\text{Cu}_{1-y}\text{Fe}_y)_2\text{O}_x$ crystals with different nominal y values of 0, 0.005, 0.013, and 0.022 grown by the floating zone method was studied by measuring M-H loops. The peak effect appears over a narrow temperature range between 20 and 40 K for y up to 2.2%, but with a small peak field of about 200 Oe. The appearance of the PE in all the Fe doped Bi-2212 can be explained by the existence of Bi^{5+} cluster regions in the Bi^{3+} 2212 matrix.

$\Delta M_{\text{max}}/M_0$ vs T/T_c and $(H_{\text{max}}-H_{\text{min}})/H_{\text{max}}$ vs T/T_c were used to characterise the peak effect. ΔM_{max} and ΔM_0 represent the width of the hysteresis loop at the secondary peak (H_{max}) and the central peak H_0 ($H=0$). H_{min} represents the field at which the magnetisation starts to increase, giving the anomalous peak. The secondary peak moves away from the central peak in a linear way as the temperature increases as indicated by $(H_{\text{max}}-H_{\text{min}})/H_{\text{max}}$ vs T/T_c , in agreement with what is found in pure Bi-2212 single crystals.

Pinning characteristics of MgB_2 near the melting curve, Supercond. Sci. Technol. 15, 619-623 (2002)

J K F Yau, M J Qin, H K Liu, S X Dou, C M Lee, Y S Han, L J Shen and X Jin

A less controversial method is used to analyse the imaginary part of the ac susceptibility measurement of MgB_2 . The pinning potential barrier $U_0(T, H)$ is obtained near the melting curve. It is found that $U_0(T, H)$ depends linearly on both the temperature and the applied field.

Influence of Ag, Cu and Fe sheaths on MgB_2 superconducting tapes, Supercond. Sci. Technol. 15, 236-240 (2002).

S. Zhou, A. V. Pan, M. Ionescu, H. Liu, and S. Dou,

Copper, iron, and silver MgB_2 sheathed tapes have been manufactured under different conditions. It has been found that copper-sheathed tapes can show a higher critical current density than iron-sheathed tapes if heat-treated at temperatures below 850°C. The influence of different overall mechanical deformation rates has been studied for tapes sheathed by all three types of metals. By increasing the deformation rate the critical current density was improved by about an order of magnitude in the case of the copper-sheathed tapes, while the critical current density of the iron-sheathed tapes remained constant.

Single- and multi-filamentary Fe-sheathed MgB_2 wires, Physica C 382,349-457 (2002).

S. Zhou, A. V. Pan, H. Liu, and S. Dou,

A novel method is proposed to increase the MgB_2 core density and, as a consequence, the critical current density of Fe-sheathed MgB_2 wires. This method involves two additional stages compared to the usual wire fabrication: post-annealing mechanical deformation and a consecutive heat-treatment. Using this method we obtained denser core structures in 7-filament wire having J_c values larger by a factor of about 4.3 than that found in the initial “in-situ” prepared mono-core wire. Independent of the manufacturing procedure, the wires showed a transport property degradation effect after being exposed to the air for 4 months.

Effect of various mechanical deformation processes on critical current density and microstructure in MgB₂ wires, Supercond. Sci. Technol. **15**, 1490-1493 (2002).

S. Zhou, A.V. Pan, H. Liu, J. Horvat, and S. Dou,

MgB₂ tapes and wires were prepared by "in-situ" reaction method. Two cycle drawing and groove-rolling were used for mechanic deformation of the samples. The critical current density J_c as a function of applied magnetic field B_a was measured and compared for all the prepared samples. Influence of the different processing at its different stages on MgB₂ microstructure was studied by scanning electron microscopy. Weak-links introduced in the superconducting core after the second cycle mechanical deformation could not be re-joined with a consecutive heat-treatment. Accordingly, for these samples $J_c(B_a)$ turned out to decrease significantly faster in increasing field than for the samples prepared with one cycle processing.

Energy Storage Materials Group

Lithium storage properties of ball milled Ni-57 mass % Sn alloy, Materials Transaction **43**, 1 63-66 (2002)

J-H Ahn, Yong-Jin Kim, G.X. Wang, M. Lindsay, H.K. Liu and S.X. Dou

Ni-57 mass % Sn alloy has been examined as a new anode material for Li-ion batteries. Li-ions can reversibly intercalate and de-intercalate in this alloy. Ball milled nanocrystalline and subsequently annealed microcrystalline Ni-57 mass% Sn alloy showed very high initial discharge capacity. The cell capacity decayed rapidly after the first discharge. The capacity of the ball milled Ni-57 mass% Sn alloy faded continuously on cycling, while the annealed alloy exhibited good cyclic properties. Therefore, Ni-57 mass % Sn alloy is an attractive intercalation host for Li ions.

Fabrication of cathode materials for Li-ion batteries using suspension slurry process, Australia Innovation Patent No. 2002100190.

S.X. Dou, K. Konstantinov, G.X. Wang and H.K. Liu

This invention is related to the fabrication of cathode materials for use in Li-ion rechargeable batteries. It is based on the discovery that in contrast to the conventional spray drying process there is no need to use a single solution or partial solution in the spray drying process, spray-drying of suspension slurry of all solid components in combination with ball-milling and firing process can achieve two distinct effects: uniforming particle size distribution and homogenising all the chemical composition.

This invention covers cathode materials: LiM_xO_y where M stands for Co, Mn, Ni, Cr etc. and $x = 1$ or 2 or 4. That is $LiCoO_2$, $LiNiO_2$, $LiMnO_2$ and $LiMn_2O_4$ and all derivatives produced by substitution and doping. This invention is potentially applicable to produce other powder materials.

Effect Of Zinc-Ion Additive To The Positive Electrode Of Rechargeable Nickel-Metal Hydride Batteries Journal of new materials for electrochemical systems, 5, 47-52 (2002)

H.K. Liu, B. Bright, C.Y. Wang, M. Lindsay, S. Zhong

Nickel hydroxide powders with three different levels of zinc-ion (0 wt%, 3 wt% and 6 wt%) were synthesized by conventional technique. All powders exhibited an irregular particle shape. The physical and chemical properties of nickel hydroxide powders prepared with zinc-ion additive, and the electrochemical properties of nickel hydroxide electrodes (positive electrode) formed with zinc-ion and pure nickel additives are studied. It is found that zinc-ion is effective in suppressing the formation of γ -phase. The cyclic voltammograms showed clearly that zinc-ion additive is successful in increasing the reversibility of the electrode reaction.

Ni/Al/Co-substituted Ni(OH)₂ as electrode materials in the nickel metal hydride cell, *J. Alloys & Compounds* **330-332**, 802-805 (2002)

C.Y. Wang, S. Zhong, D.H. Bradhurst, H.K. Liu and S.X. Dou “

It is found that the phase of the product formed after nickel is co-precipitated with both aluminium and cobalt cations is α -Ni(OH)₂. In this paper, its physical characteristics have been identified with scanning electron microscopy (SEM) and X-ray diffraction (XRD). It was used as an electrode material in an open Ni/MH cell and its electrochemical properties have been examined. The results show that the electrochemical properties have been improved by adding Al and Co. The electrode fabricated from the nickel hydroxide with additives of Al and Co show a better reversibility and charge-discharge capability compared with the electrode with no additive. Also a maximum capacity of 319 mAh/g was obtained for this electrode.

Structural study of Al-substituted nickel hydroxide, *Solid State Ionics* **148**, 503-508 (2002)

C.Y. Wang, S. Zhong, K. Konstantinov, G. Walter, H.K. Liu

Powder X-ray diffraction (XRD) is employed to identify the phase structure of Al-substituted nickel hydroxide, and its structural change after ageing treatment or charge/discharge cycles. The cell constants and the crystalline size of nickel hydroxides have been obtained by analysing the XRD pattern with Si as an internal standard. Results show that Al-substituted α -phase nickel hydroxide is very stable in strong alkaline medium even after 100 charge/discharge cycles.

Development of New Positive Compounds for Lithium-ion Batteries, Australia Innovation Patent No. 2002100403

G.X. Wang, S. Bewlay, K. Konstantinov, H.K. Liu, S.X. Dou

A series of new positive compounds have been synthesised with a general formula of $\text{LiM}_x\text{M}'_y\text{O}_2$, where $0 \leq x \leq 1$, $y = 1 - x$. M and M' are the metal elements selected from the group consisting of Co, Mn, Fe, V, Ti, Mg, Ni, Al, Zn, Cu, In, Ca, Ba, Sr, Mo, Sb, Ge, Si and Nb. These $\text{LiM}_x\text{M}'_y\text{O}_2$ compounds have a layered rock-salt type rhombohedral structure. The synthesis of these compounds was carried out by a variety of innovative techniques such as solution spray drying, slurry spray drying and chemical co-precipitation. The synthesised positive compounds have a homogeneous crystal size and particle size distribution as well as a controlled crystal morphology. Some of the $\text{LiM}_x\text{M}'_y\text{O}_2$ compounds delivered a high electrochemical capacity in the range of 160 – 180 mAh/g and good cycle life. The corresponding production techniques were developed, which can easily be scaled-up for high volume industrial production. The current innovation provides new positive electrode materials with high energy density for lithium-ion battery industry.

An investigation of cobalt oxides as anode materials for Li-ion batteries, *J. Power Sources* **109** (2002) 142-147.

G.X. Wang, Y. Chen, K. Konstatinov, Matthew Lindsay, H.K. Liu and S.X. Dou

Cobalt oxides as anode materials for Li-ion batteries were investigated using a variety of electrochemical characterisation techniques. The CoO electrode demonstrated stable reversible lithium storage capacity about 300 mAh/g even after 30 cycles. The reactivity of cobalt oxides could be attributed to nanosize particles of lithiation products.

G.X. Wang, Y. Chen, K. Konstantinov, Jane Yao, Jung-ho Ahn, H.K. Liu and S.X. Dou

Nanosize cobalt oxides (Co_3O_4) were synthesised by chemical decomposition of cobalt octacarbonyl in toluene at low temperature. Electrochemical properties of as-prepared Co_3O_4 as anodes in Li-ion cells were tested. The nanosized Co_3O_4 electrode demonstrate a stable reversible lithium storage capacity of 360 mAh/g within 30 cycles. The reactivity of as-prepared Co_3O_4 in Li-ion cells could be attributed to nanosize particles of Co_3O_4 and its lithiation products.

Cathode Materials for Rechargeable Lithium Batteries and a Process for Production, Australia Innovation Patent No. 2002100000.

G.X. Wang, K. Konstantinov, H.K. Liu and S.X. Dou

The motivation of this invention is to provide a set of production technologies for producing lithium cobalt oxide materials with high specific capacity and long cycle life. The as-prepared lithium cobalt oxides cathode materials must have good electrochemical properties, such as high capacity and a satisfactory cyclability. With this target in mind, the present invention pays much attention to details of the preparation procedure. The precursor materials must be selected to have maximum reactivity. Currently, two different processes are provided for production of lithium cobalt oxide. The materials are calcined at relatively low temperature and over a short period. Therefore, lithium loss and composition fluctuation can be avoided.

The first aspect of the present invention is to provide a process to produce lithium cobalt oxide via a solid-state reaction. The precursor materials, (cobalt oxides and lithium compounds), are mixed using high-energy ball milling. The elements lithium and cobalt are thus mixed at the quasi-atomic level. This process guarantees the homogeneous distribution of lithium and cobalt in the final product. The mixture is then formed to a shaped bulk. The shaped bulk is then fired at a temperature between 500 °C and 900 °C for 6 – 24 hours in a specially designed furnace which has uniform temperature distribution. After sintering, the compact bulk is disintegrated into powders.

The second aspect of the present invention is to provide a production process for lithium cobalt oxides via a solution route. The cobalt acetate salt and lithium carbonate are dissolved in diluted acetic acid to form a homogeneous solution. Acetic acid is chosen because decomposition of acetic salt presents no pollution problems, which is an advantage over other acids such as sulphuric, nitric or hydrochloric acids. In this case, the elements lithium and cobalt are mixed at the atomic level. The solution is then spray dried to obtain a dry powder. These powders are then sintered at a temperature between 500 °C and 900 °C for 6 – 24 hours. During the sintering process, acetic salts decompose to their corresponding oxides. These oxides react each other to form LiCoO_2 compounds. After sintering, the lithium cobalt oxide bulk is ground to obtain a fine powders. The produced lithium cobalt oxides were characterised by X-ray diffraction, scanning electron microscopy, particle size measurement and specific surface area measurement. The composition of LiCoO_2 compounds was determined by ICP measurement.

The electrochemical properties of the as-prepared lithium cobalt oxide powders were tested in a laboratory lithium testing cell. The LiCoO_2 powders were dispersed in an organic binder together with carbon black to form a slurry. The slurry is then coated onto the Al foil. The coated layer of LiCoO_2 was vacuum dried and pressed to obtain a consolidated compact electrode. Lithium test cells were assembled in an argon filled glove-box using lithium foil as counter electrode. An organic electrolyte containing 1 M lithium ions was used as electrolyte for testing cell's construction. A porous plastic film was used as separator to separate cathode and anode which allowed lithium ions to go through. These cells were cycled over the voltage range 3.0 V - 4.4 V using constant current. The capacity and cycle life were thus determined via such cycling test.

Li storage properties of carbon nanotubes prepared by chemical vapour deposition, J. of Metastable and Nanocrystalline Materials Vol. 12, p18, 2002.

G.X. Wang, J. Yao, M. Lindsay, Y. Chen, H.K. Liu, S.H. Ryu and J.-H. Ahn

Multiwalled carbon nanotubes were prepared using Chemical Vapor Deposition (CVD). The morphology and microstructure of carbon nanotubes were observed via HRTEM. The as-prepared carbon nanotubes are entangled to bundles with a diameter of several tenth nano meters. Electrochemical properties of carbon nanotubes as anodes in lithium-ion batteries were investigated via a variety of electrochemical testing techniques. The carbon nanotube electrode demonstrated a reversible lithium storage capacity of 340 mAh/g with good cyclability at moderate current density. The kinetic properties of lithium insertion in carbon nanotube electrodes were characterised via a.c. impedance measurements.

Keywords: Carbon nanotubes, chemical vapour deposition, lithium-ion battery, a.c. impedance spectroscopy.

A new process for fabrication of metal-hydride electrodes for nickel-metal hydride batteries, Journal of Alloys and Compounds 330-332 (2002) 760 – 765.

S. Zhong, A. Howes, G.X. Wang, D.H. Bradhurst, C.Wang, S.X. Dou and H.K. Liu

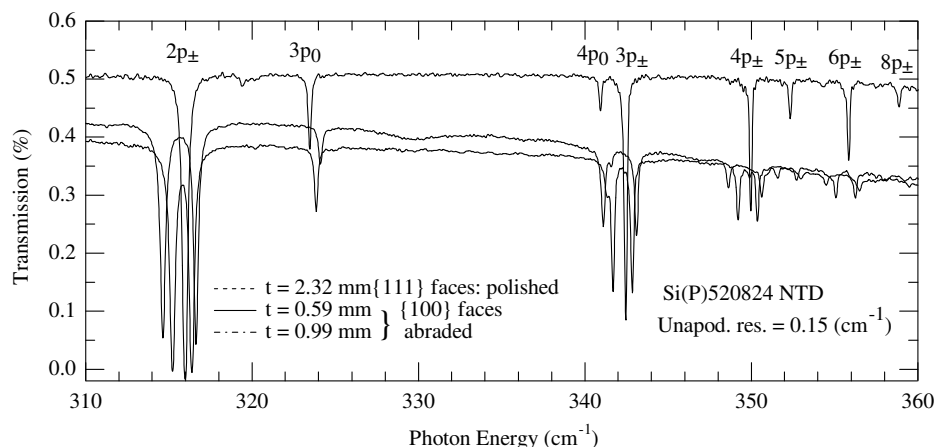
A new method for fabricating a metal-hydride electrode for nickel-metal hydride (Ni-MH) batteries is reported. An expanded copper alloy mesh was used as the electrode substrate to substitute for the conventional nickel foam or nickel-based substrate in order to reduce the cost and increase the processing efficiency. The effects of addition of a dry conductive binder to the electrode active material, the adherence of the electrode active material to the copper-based substrate under pressure and their effect on the open test cells and commercial cells were investigated. Significant improvements to the discharge capacity and cycle life have been achieved by using this new electrode fabrication technique.

Solid State Physics Group

Bulk Homogeneous Uniaxial Stress Arising from Surface Damage of Crystalline Silicon and Germanium, 7th International Conference on the Structure of Surfaces, Newcastle, NSW, July, 2002.

P. Fisher, R .E. M. Vickers and D. C. Lau

This paper was fully refereed and will appear in an issue of Surface Review and Letters. An example of the perturbation to the spectrum of phosphorus in silicon is given in the following figure.



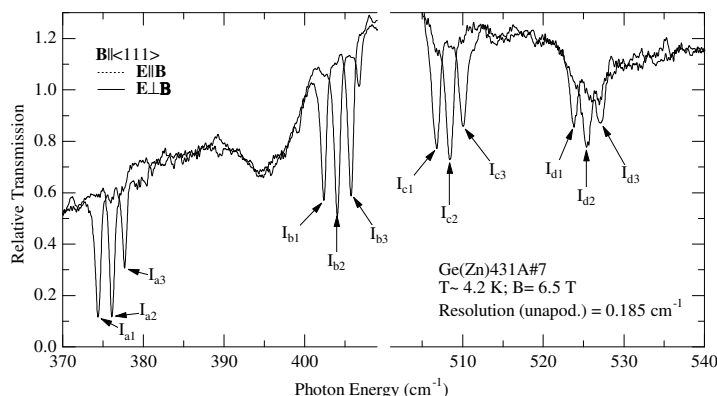
The contribution made by Mr Lau to this paper was extracted from his Fourth Year Materials Engineering Thesis submitted in 2001; he was awarded a First Class Honours degree.

Two spectra of Si(P) abraded with 15 μm alumina and one with polished optical faces.

Coulomb Related Landau Spectra of Axial and Double Acceptors in Germanium, 10th International Conference on Shallow-Level Centers in Semiconductors, Warsaw, Poland, July, 2002. This paper was refereed and has appeared as *phys. stat. sol. (b)* **0**, 683 (2003).

P. Fisher, R. E. M. Vickers and K. Ishida

Parts of the Landau spectra of neutral zinc in germanium are shown in the figure below.



Landau spectra of neutral zinc in germanium.

Mr. Ishida completed the Fourth Year of his Undergraduate degree from the University of Electro-Communications, Tokyo, Japan, at Wollongong. His contribution has been submitted in his Fourth Year thesis. As a result of his experience at Wollongong, he has returned here to embark on a Postgraduate Degree with Fisher and Vickers.

One of the above papers was also accepted for presentation at the most prestigious conference series on semiconductors, *viz.*, The 26th International Conference on the Physics of Semiconductors, held in Edinburg, Scotland. We decided not to attend this conference for two reasons. First, our research funds were not sufficient for the expenses involved in attending two conferences overseas, even though they were back-to-back, while, secondly, the University refuses to accept that selection of papers at these prestigious conferences involves a very rigorous culling of the abstracts (only approx. 50% are accepted) which is fully equivalent to the refereeing carried out by standard research journals.

Ferromagnetic resonances in polycrystalline $La_{0.8}Li_{0.2}MnO_3$, Proc. Physical Phenomena at High Magnetic Fields-IV, Santa Fe, USA 19-25/10/01, Ed: G Boebinger, Z. Fisk, L.P. Gor'kov, A. Lacerda, J.R. Schrieffer, 459-462 (2002)

R.A. Lewis, X.L. Wang, S.X. Dou, N. Biskup and J.S. Brooks

Report on magnetic resonances observed in the doped lanthanum manganite $La_{0.8}Li_{0.2}MnO_3$ (LLMO) below the Curie temperature $T_c \sim 235K$. Fields up to 30 T were employed. The data are compared with that from the archetypal colossal magnetoresistance perovskite $La_{0.7}Ca_{0.3}MnO_3$ (LCMO) taken under similar conditions. In contrast to LCMO, LLMO exhibits two resonances, one above and one below the LCMO resonant field. These are attributed to a ferromagnetic interaction and a canted ferromagnetic interaction.

Effect of strong terahertz radiation on magnetoconductivity in two dimensions, Proc. Physical Phenomena at High Magnetic Fields-IV, Santa Fe, USA 19-25/10/01, Ed: G Boebinger, Z. Fisk, L.P. Gor'kov, A. Lacerda, J.R. Schrieffer, 52-55 (2002)

R.A. Lewis, X. Xu, P.M. Koenraad and I.V. Bradley

The interaction between strong THz radiation from a free electron laser and an electron sheet in a high-mobility, low density, GaAs/Al/GaAs structure has been investigated in magnetotransport experiments over a wide range of wavelengths, intensities, magnetic fields and temperatures. Photovoltage and photocurrent effects are evident in both longitudinal and transverse potential differences. Broad cyclotron resonance is observed to high temperature and connected with a decrease in electron density. The change in electron temperature under THz radiation is estimated from changes in the magnitude of the magnetoresistivity oscillations at low lattice temperature. The effect of the magnetic field is to suppress the rise in electron temperature relative to the zero field case.

Dynamic screening and collective excitation of an electron gas under an intense terahertz radiation, Phy. Rev. B **65**, 153107 (2002)

C. Zhang,

By using time-dependent wavefunctions for electrons under an intense laser, we calculated the charge density fluctuation of an electronic system under a weak probing potential. The dielectric function of the system as a function of the laser frequency and intensity is derived. The spectrum of the collective excitation is calculated. The spectrum exhibits the contribution of various multi-photon processes.

Frequency-dependent electrical transport under an intense terahertz radiation, Phys. Rev. B **66**, 081105 (2002)

C. Zhang,

By using a formalism based on quantum transport equation, we study the current response of an electron gas strongly coupled to an intense terahertz laser. The effect of laser is treated exactly which gives rise to the electron-photon side-bands. Our formalism includes up to the second order in electron-impurity scattering and to any order in optical transitions between the side-bands. Resonant scattering can occur when the frequency of the probing field equals the multiple of terahertz laser frequency. The usual linear response theory is the zero-photon term in our formalism. This result can be applied to study the electrical transport in strongly coupled electron-photon systems. One of such systems is a two-dimensional semiconductor structure under an intense terahertz radiation.

Current & Ongoing Research Projects

ARC Large/Discovery Grants Scheme

Current limiting mechanism in Ag sheathed (Bi,Pb)SrCaCuO tapes with magneto-optical imaging and magnetic force microscopy

Years funded:	2000	2001	2002
Amount funded:	\$62,488	\$66,677	\$67,261
Chief Investigator:	H.K. Liu		
Partner Investigator:	A. Polyanskii		
Assoc. Investigator:	J. Horvat, D. Larbalestier		
Postgrad. Student:	G. Li		

The mechanism of supercurrent flow, which underlies the technological success of high temperature superconducting tapes, remains unclear. The aim of this proposal is to understand, determine and model the current limiting mechanisms in Ag/Bi-based high temperature superconducting tapes by using magneto-optical imaging and magnetic force microscopy combined with other techniques such as transport and magnetic measurements. It is expected that the outcomes of this study will be invaluable in the development of appropriate materials processing techniques to improve the critical current density.

Enhancement of transport critical current density in magnetic fields of Ag/BiPbSrCaCuO tapes by fission tracks

Years funded:	2001	2002	2003
Amount funded:	\$71,945	\$77,589	\$77,888
Chief Investigator:	S.X. Dou		
Research Fellow:	T. Silver		
Postgrad Students:	D. Marinaro, D. Milliken		

An important application of high temperature superconductors (HTS) is in the area of high current and high magnetic field where a high critical current density, J_c , in strong magnetic fields is essential. It is well accepted that J_c of Ag/BiPbSrCaCuO tapes is limited by the grain connectivity in the self-field, but by flux pinning in an applied field. The objective of this project is to enhance flux pinning by using a combination of stable uranium compound doping and thermal neutron irradiation to produce fission fragments to act as pinning centres. The expected outcomes will be improved J_c in magnetic fields and minimised anisotropy of HTS with radioactivity to a level acceptable for handling.

Growth, characterisation and flux pinning behaviour of doped $TiSr_2Ca_2Cu_3O_y$ and $TiSr_2CaCu_2O_y$ and high temperature superconducting single crystals

Years funded:	2001	2002	2003
Amount funded:	\$59,954	\$58,191	\$58,416
Chief Investigator:	H.K. Liu		
Assoc. Investigator:	M. Ionescu, X.L. Wang		
Researcher:	Z.X. Cheng		

$TiSr_2Ca_2Cu_3O_y$ (TISr-1223) and $TiSr_2CaCu_2O_y$ (TISr-1212) exhibit significant improvement in critical current at high magnetic fields over the TI- and Bi-based high temperature superconductors (HTS). Flux pinning for both compounds has not been well investigated because of the extreme difficulties involved in growing single crystals. The aim of the proposed research is to investigate the growth, characterisation and flux pinning behaviour in Pb or Ba doped and undoped TISr-1212 and 1223 single crystals. This study will lead to a better understanding of the intrinsic flux pinning properties of both phases and be beneficial for application involving TI-or Bi-based HTS films and tapes.

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. Soltanian, S. Keshavarzi				

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.

Enhancement and elucidation of flux pinning in doped Bi-Sr-Ca-Cu-O high temperature superconducting single crystals

Funded:	2002	2003	2004
Amount Funded:	\$61,184	\$62,967	\$62,967
Total Funding:	\$187,118		
Project ID:	DP0211328		
Chief Investigator:	X.L. Wang		

The proposed project aims to study the effects of elevated doping on the intrinsic electromagnetic properties of Bi-Sr-Ca-Cu-O high temperature superconducting (HTS) single crystals grown by two-dimensional and spiral-growth mechanisms with a particular focus on structure, conductivity and thermal neutron irradiation. Studies of the relationship between microstructures, anisotropy and flux pinning will lead to a better understanding of the pinning behaviour of Bi-based HTSC. The outcome will be better methods for introducing suitable pinning centres into Bi-based high temperature superconductors.

Analysis, simulation, fabrication and characterization 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:	B.C. Lough, Z. Dou, S.P. Lee		

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 revolutionize 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		

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 charge 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.

ARC Research Fellowships

Optimisation of thermal and mechanical processing and critical current density of Ag/(BiPb)-2223 Tapes

Years funded:	1999	2000	2001	2002	2003
Amount funded:	\$95,278	\$90,666	\$92,238	\$94,230	\$96,817
Chief Investigator:	H.K. Liu, Australian Professorial Fellow				

This proposal studies mechanisms of novel processing techniques that either together or separately are expected to enhance the critical current density of Ag-sheathed $(\text{Bi,Pb})_2\text{Sr}_2\text{Ca}_2\text{Cu}_3\text{O}_{10}$ (Bi:2223). These include a cryogenic process for mechanical deformation, a two-step sintering for heat treatment, a quench, followed by a rapid heating used in between thermal cycles, the Bi:2223 formation-partial-decomposition process and partial decomposition under hot deformation. All these processes center about the kinetics and thermodynamics of phase transformation during each stage of processing.

Combination of these innovative processes will result in an optimised process that leads to the best microstructure, substantially reduced processing time and a high J_c in Bi:2223 tapes, making them suitable for applications.

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

High Energy Battery for Electric Vehicles

Years funded:	2000	2001	2002
Amount funded:	\$71,000	\$68,000	\$75,000
Chief Investigator:	H.K. Liu, D. Bradhurst, S. Zhong		
Postgrad Student:	C.Y. Wang		
Industry Partner:	Electric Transit Pty Ltd, China Liaoning Suppo Battery Ltd, Australian Battery Technology		

The aims of the research will be to study a range of advanced battery electrodes, leading to the development of a high energy battery suitable for powering an electric test vehicle to be provided as an in-kind contribution by our Australian industrial partner. The significance of this research is that it will encourage advanced battery utilisation and manufacture in Australia. The expected outcomes will be the use of advanced batteries by our industrial partner in their Australian-built vehicles and an increased awareness of the advantages of these batteries in competition with the lead/acid types currently used.

Investigation of Bi-2223/Ag superconductor winding for application in an electrical fault current limiter

Years funded:	2000	2001	2002
Amount funded:	\$99,700	\$98,000	\$97,000
Chief Investigator:	S.X. Dou		
Partner Investigator:	M. Apperley		
Associate Investigator:	C. Cook, G. Grantham		
Research Fellow:	J.X. Jin		
Industry Partner:	Australian Superconductors Ltd		

As electrical power systems grow in capacity, increased fault current must be managed. Existing electrical equipment in the system has to be able to cope with an increased fault level. The costs of upgrading existing equipment can be enormous; therefore it is necessary to develop a fault current limiter (FCL) which cannot be built using conventional conductors. High T_c superconductors (HTSC) provide an opportunity to develop such an FCL. A HTSC FCL, both its principle, design techniques and performance, will be studied in relation to new HTSC technology. This research will assist the development of a practical HTSC and associated technology for HTSC applications in electrical engineering.

Solid-state rechargeable lithium batteries for telecommunication and portable electronic devices

Years funded:	2001	2002	2003
Amount funded:	\$60,234	\$74,080	\$63,922
Chief Investigator:	GX Wang, H.K. Liu, S. Zhong		
Partner Investigator:	X.Q. Yang		
Assoc. Investigator:	D.H. Bradhurst		
Industry Partners:	Australian Battery Technology, Lexel Battery Ltd.		

It is aimed to develop solid state rechargeable lithium polymer batteries and thin film microbatteries for telecommunications and miniature electronic devices. The significance of this project is to develop advanced solid-state rechargeable technology and stimulate advanced battery manufacture in Australia. The expected outcome will be to produce prototype lithium polymer batteries for cellular phones, notebook computers and palm computers. Thin-film microbatteries will also be fabricated using a pulsed laser ablation technique.

Experimental development of thermionic cooling for domestic refrigeration

Years funded:	2001	2002	2003
Amount funded:	\$22,292	\$22,292	\$22,292
Chief Investigator:	R.A. Lewis, C. Zhang		
Industry Partner:	Email Limited		
Postrad Student:	Z. Dou		

The aim is to prove in practice the concept of solid-state cooling by thermionic emission for domestic refrigeration. The proposed experimental work follows naturally from the recent theoretical advances made in this area by us and others. A structure consisting of very thin, alternating layers of semiconductors is calculated to have high cooling efficiency. In contrast to standard compressor-based refrigerators, a refrigerator based on the new concept has no moving parts, is silent, vibration free, environmental friendly and low maintenance. The project links experts in semiconductor physics theory and experiment with Australia's largest manufacturer of domestic refrigerators, whose factory is regionally based (Orange, NSW).

Developing New Cathode Materials for Lithium-ion Batteries Using Australian Mineral Resources

Years funded:	2002	2003	2004
Amount funded:	\$83,000	\$84,000	\$84,000
Total funding:	\$251,000		
Project ID:	LP0214179		
Chief Investigator:	Prof Shi Xue Dou, Dr G Wang		
Partner Investigators:	Prof J Lee		
Research Fellow:	K. Konstantinov		
APA(I) Award(s):	S. Bewlay		
Industry Partner(s):	Sons of Gwalia Ltd. OM Group		

This project will bring together expertise in electrochemistry, materials science and structure characterisation to conduct collaborative research with Australian industry partners, Queensland Nickel Technology Pty Ltd and Sons of Gwalia Ltd. The aims of this project will be to investigate a series of cathode materials for use in lithium-ion batteries. The significance of this research is that the technology for preparing a series of new electrode materials for lithium-ion batteries will be developed by taking advantage of abundant Australian minerals resources. The expected outcomes will be to identify several new cathode materials with high energy density, long cycle life, low toxicity and low cost.

Fabrication and Characterisation of Magnesium Diboride Superconducting Wires

Years funded:	2002	2003	2004
Amount funded:	\$110,000	\$100,000	\$100,000
Total funding:	\$310,000		
Project ID:	LP0219629		
Chief Investigator:	Prof Shi Xue Dou, Dr XL Wang, Dr M Ionescu		
Partner Investigators:	Dr MD Sumption		
APA(I) Award(s):	Yue Zhao		
Industry Partner(s):	Alphatech International The Hyper Tech Research Inc.		

The newly discovered superconductivity at 40K in magnesium diboride (MgB_2) opens a technical window to a range of electric power applications, previously thought accessible only with high temperature superconductors. The aim of the proposed project is to investigate the fabricability and properties of MgB_2 superconducting wires using a number of processing techniques established in previous low temperature and high temperature superconductors. The expected outcome is to have a MgB_2 conductor that has a higher performance in a field than niobium-titanium (NbTi) alloy, a higher operating temperature (up to 20K), but at a cost less than currently commercial NbTi wire.

Investigation of Nano-materials for use in Lithium Rechargeable Batteries

Years funded:	2002	2003	2004
Amount funded:	\$67,000	\$60,000	\$60,000
Total funding:	\$187,000		
Project ID:	LP0219309		
Chief Investigator:	Prof Hua Kun Liu, Dr S Zhong		
Partner Investigators:	A/Prof J Ahn		
APA(I) Award(s):	L. Yuan		
Industry Partner(s):	Sons of Gwalia Ltd QNI Technology Pty Ltd Lexel Battery Ltd		

Lithium ion batteries are emerging as a new generation of rechargeable batteries for power sources of portable electronics. The aim of this project is to explore potential applications of novel nano-materials such as intermetallic alloys, transition-metal oxides, and carbon nanotubes as anode materials in lithium-ion rechargeable batteries. Significance and expected outcomes will be the development of alternative anode materials with improved performance in energy capacity and cycle life over existing anode materials. This could open opportunities for Australian mineral companies to take advantage of the developments to produce value-added new products.

Fabrication of Magnesium Diboride (MgB_2) thick films

Years funded:	2002	2003	2004
Amount funded:	\$22,545	\$22,545	\$22,545
Total funding:	\$67,635		
Project ID:	LP0228370		
Chief Investigator:	Dr X L Wang		
APA(I) Award(s):	Q.W. Yao		
Industry Partner(s):	SFC Enterprises Pty Ltd		

The recent discovery of superconductivity at 39 K in MgB_2 has stimulated considerable interest in terms of both fundamental research and applications. The purpose of the proposed project is to conduct fundamental studies on the synthesis, structures and microstructures, and physical properties of doped and undoped MgB_2 thick films. The ultimate goal of this study is to fabricate high quality MgB_2 thick films on different substrates and to gain a better understanding of their various properties with a view to device application.

ARC linkage-infrastructure

Next generation organic electronic and optoelectronic device fabrication facility,

Years funded: 2002
Amount funded: \$195,000
Project ID: LE0239044
Chief Investigator: Hamilton/Gal/Lamb/Bursill/Meredith/McKenzie/Lewis

1. We have custom designed and ordered substantial equipment for making and testing polymer devices, much of which is now in which place. The outstanding items are being built in the USA and UK, and are to be delivered in the next 6-8 weeks.
2. The new infrastructure is already in use: We have performed initial measurements of the electrical properties of polymer films at UNSW, and built a customised low noise electronics system which has been used to test the performance of novel polymer solar cells at UQ.
3. We are just about to appoint a physical chemist to complete installation of the remaining equipment items at UNSW.
4. The grant is attracting top scientists back to Australia, and is supporting new research activities both at UNSW and UQ.

Linkage International Awards

Development of Solid-state cooling chips

Years funded: 2002 2003
Amount funded: \$11,700 9,500
Total funding: \$21,200
Project ID: LX0240472
Chief Investigator: A/Prof RA Lewis, Dr C Zhang - University of Wollongong
Prof Q Huang - Institute of Physics, CAS

In this project, we aim to develop semiconductor cooling elements that can be directly integrated into existing circuits and devices. The proposed international collaboration combines the expertise of the Chinese Academy of Science in device fabrication with the expertise of the University of Wollongong in device characterisation and modelling.

Investigation of a series of metallic substrate materials suitable for developing long Y-Ba-Cu-O superconductors

Years funded: 2002 2003 2004
Amount funded: \$19,396 \$17,596 \$17,596
Total funding: \$54,588
Project ID: LX0211084
Chief Investigator: Prof Hua Kun Liu - University of Wollongong
Prof D Shi - University of Cincinnati

Researchers from Institute for Superconducting and Electronic Materials, the University of Wollongong (UoW) & the Dept. Mat. Sci & Eng., University of Cincinnati (UC) in USA will build strong collaborations through joint research on a series of metallic substrate materials. Significance: The research work will contribute to the development of the second generation of high temperature superconducting wire technology. Expected outcomes: strengthen international research experience for junior researchers and develop new collaborations between senior researchers from UoW in Australia and UC in USA.

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:	A/Professor C. Zhang, A/Professor R.A. Lewis CI Prof KA Chao Lund University, Sweden		

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 integrable. 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.

Linkage International Fellowships

Composite cathode Materials for Lithium Ion Battery Using Chemical Coating Technique.

Years funded:	2002
Total funding:	\$69,424
Chief Investigator:	Prof SX Dou - UoW Prof J Lee - Korean Advanced Institute of Science and Technology

Commercial Li-ion batteries have LiCoO₂ as a cathode material due to its excellent cycle stability and rate capability. However, cobalt is a relatively rare and very expensive transition metal, so attention has been focussed on LiMn₂O₄ with a view to taking advantage of its low cost and environmentally friendly nature compared to LiCoO₂. The aim of this is to develop new composite cathode materials by using a LiCoO₂. The aim of this project is to develop new composite cathode materials by using a LiCoO₂ coating on Li-Mn-O materials. The expected outcome is a new cathode material which has high-energy capacity, long cycle life and low cost.

Research Infrastructure Equipment and Facilities (RIEF) Scheme

A 200 keV Analytical transmission electron microscope for advanced materials research

Years funded:	2002
Amount funded:	\$580,000
Chief Investigators:	D. Dunne, S.X. Dou, R. Dippenaar, Z. Chen, G. Dennis, F. Barbaro
Collaborating Institutions:	University of Western Sydney, BHP Billiton

Transmission electron microscopy is one of the most powerful techniques available for investigating and characterising the fine structures, compositions and crystallographic features of geological, biological and engineering materials. It is an essential tool in the arsenal of characterisation equipment for any organization involved in high quality research and development of materials. The Illawarra region of NSW currently lacks a modern analytical transmission electron microscope to support a wide range of internationally competitive materials research. The aim of this application is to correct this deficiency.

Systemic Infrastructure Initiative Grants

Department of Education, Training and Youth Affairs

Nanofabrication facilities for processing of novel multilayer materials

Years funded:	2002	2003	2004
Amount funded:	\$440,000	\$550,000	\$487,500
Institutions contribution:	\$192,500		
Total funding:	\$1,670,000		
Chief Investigators:	Prof SX Dou, M. Ionescu, X.L. Wang, H.K. Liu, G.X. Wang T. Silver, R.A. Lewis – University of Wollongong A/Prof S. Ringer – University of Sydney Prof GQM Lu – University of Queensland Prof EM Goldys – Macquaire University Prof M. M Wilson – UTS A/Prof DN Jamieson, University of Melbourne A/Prof J. Mazierska - Jame Cook University Dr. J. Low - Curtin University of Technology Dr. R. Ramer – UNSW Prof. G. Smith – UTS Prof. M. Skyllas-Kazacos - UNSW		

The proposal seeks to obtain nanofabrication facilities including a modified metallorganic chemical deposition (MOCVD), electron beam evaporation (EBE) and lithography facilities for the processing of novel multilayer materials and devices. These facilities will significantly enhance the national capacity in nanofabrication for a wide range of novel materials and devices.

ARC Small Grants Scheme

Magnetic shielding in MgB_2/Fe superconducting wires

Amount funded: \$9,700
Chief Investigator: Josip Horvat

Electric Losses of superconductor thin strips in perpendicular magnetic fields

Amount funded: \$8,600
Chief Investigator: MengJun Qin

Novel study of HT-Superconductor in a Resonant Electronic Circuit.

Amount funded: \$8,000
Chief Investigator: Jian Xun Jin

Preparation of Carbon Nanotubes for Energy Storage

Amount funded: \$6,000
Chief Investigator: Guoxiu Wang

Theory and simulation of terahertz imaging

Amount funded: \$5,000
Chief Investigator: Chao Zhang

Near Miss Grants

Investigation of new superconductors: magnesium diboride (MgB_2) compounds

Amount funded: \$6,000
Chief Investigators: Hua Kun Liu, Xiaolin Wang

Cool chips: developing on-board solid-state cooling for electronic devices

Amount funded: \$6,000
Chief Investigators: Chao Zhang, Zhixin Chen, Roger Lewis

Australian Institute of Nuclear Science & Engineering

Special Postgraduate Award

Year funded: 2002
Amount funded: \$5,500
Chief Investigator: S.X. Dou
Postgraduate Student: D. Marinaro

Thermal neutron irradiation of uranium-doped superconductors

Year funded: 2002
Amount funded: \$1,710
Chief Investigator: T. Silver

Studies of novel perovskite cobalt compounds

Year funded: 2002
Amount funded: \$10,818
Chief Investigator: X.L. Wang

Studies of magnetic properties of doped Y-Sr-Co-O perovskite cobalt compounds

Year funded: 2002
Amount funded: \$27,818
Chief Investigator: X.L. Wang

Enhancement of critical current density in newly discovered MgB₂ superconductors using hot isostatic press and hot press techniques

Year funded: 2002
Amount funded: \$2,300
Chief Investigator: X.L. Wang

University of Wollongong

University Research Council, ISEM Performance Indicator

Year funded: 2002
Amount funded: \$125,745

Conferences & Invited Seminars

2002 Korean Photonics Forum , January 2002, Seoul, Korea

C Zhang (keynote speaker) Nonlinear transport under intense terahertz radiation

International Meeting on Lithium Batteries, Monterey, CA, U.S.A. 23-28th June, 2002

J.H. Ahn, G.X. Wang, H.K. Liu, S.X. Dou	Nanoparticle-dispersed PEO Polymer Electrolytes for Li Batteries
J.H. Ahn, G.X. Wang, Y. Yao, H.K. Liu, S.X. Dou	Tin-Based Composite Materials as Anode Materials for Li-ion Batteries
Y. Chen, G. Wang, K.Konstantinov, and H. Liu	Synthesis and Characterization of $\text{LiCo}_x\text{MnyNi}_{1-x-y}\text{O}_2$ as a Cathode Material for Lithium Secondary Batteries
Z.P. Guo, K. Konstantinov, G.X. Wang, H.K. Lliu and S.X. Dou	Preparation of Orthorhombic LiMnO_2 Material via the Sol-gel Process
M. Lindsay, G. Wang, and H.K. Liu	Al-based Anode Materials for Li-ion Batteries
G.X. Wang, J.H. Ahn, J. Yao, S.H. Ryu, M. Lindsay, Y. Chen, H.K. Liu, S.X. Dou	Preparation and Characterisation of Carbon Nanotubes for Energy Storage
G.X. Wang, K. Konstantinov, J. Yao, S. Bewlay, Y. Chen, H.K. Liu, S.X. Dou	Multiple Ions Doped Lithium Nickel Oxide as Cathode Materials for Lithium-Ion Batteries
K. Konstantinov, G.X. wang, J. Yao, H.K. Liu and S.X. Dou	Stoichiometry Controlled High Performance LiCoO_2 Electrode Materials Prepared by a Spray Solution Technique

Korean Institute of Machinery & Materials, 7th June, 2002

S.X. Dou (invited seminar talk) Enhancement of critical current density of MgB_2 by nano-doping

Korean Advanced Institute of Science & Technology, 9th June, 2002

H.K. Liu (invited seminar talk) Cathode materials for lithium ion rechargeable batteries

International Conference on Advanced Materials, organised by the European Materials Society (E-MRS), 18-21 June, 2002, in Strasbourg, France

M. Ionescu (invited) Growth of MgB_2 Thin Films by Pulsed Laser Deposition

International Symposium on Ultrafast Phenomena and Terahertz Waves July 2002, Beijing, P.R. China

C Zhang (invited speaker) Quantum transport in electronic system in terahertz regime

10th International Conference on Shallow-Level Centers in Semiconductors, Warsaw, Poland, July, 2002

P. Fisher, R. E. M. Vickers and K. Ishida Coulomb Related Landau Spectra of Axial and Double Acceptors in Germanium

7th International Conference on the Structure of Surfaces, Newcastle, NSW, July, 2002

P.Fisher, R .E. M. Vickers and D. C. Lau Bulk Homogeneous Uniaxial Stress Arising from Surface Damage of Crystalline Silicon and Germanium

Applied Superconductivity Conference “Superconductors in the Marketplace”,
Houston, Texas, USA, 4-9th August 2002

S.X. Dou (invited speaker at Breaking News Session)	Nano SiC Substitution Induced Pinning in MgB ₂
S.X. Dou, S. Soltanian, S. Zhou, J. Horvat, X.L. Wang, M.J. Qin, M. Ionescu, A. Pan and H.K. Liu	Superconductivity, Critical Current Density and Flux Pinning in SiC-doped MgB ₂
J. Horvat, X.L. Wang, S. Soltanian, S.X. Dou	Magnetic Shielding in MgB ₂ /Fe Superconducting Wires
R. Zeng, M.H. Apperley, H.K. Liu, S.X. Dou	Processing and Characterisation of AgMg Sheathed Bi-2223 Tapes
S. Zhou, A.V. Pan, H.K. Liu, J. Horvat, S.X. Dou	Effect of Various Mechanical Deformation Processes on Critical Current Density and Microstructures
S.X. Dou, X.L. Wang, S. Soltanian, J. Horvat, S.H. Zhou, A.H. Li, H.K. Liu, S.X. Li, M. Sumption, E.W. Collings	Fabrication and Improvement of Critical Current Density in Metal Clad MgB ₂ Superconducting Wires and Tapes by in-situ Reaction Process

International Conference on Physics and Chemistry of Molecular and Oxide
Superconductors, 13-18th August 2002, Taiwan, R.O.C.

S.X. Dou, S. Zhou, S. Soltanian, A. Pan, M. Ionescu, P.R. Munroe, J. Horvat, X.L. Wang, H.K. Liu (invited talk)	Superconductivity, Critical Current Density and Flux Pinning in Superconductor MgB _{2-x} Si _x C _x by Nanoparticle SiC Doping
S.Zhou, H.K. Liu, J. Horvat, S.X. Dou	Effect of Ti Doping on the Superconductivities of MgB ₂ /Fe Wires”

Symposium for Chinese Scholars on Magnetoelectronics and Superconducting
Electrical Engineering, Beijing, China, 15-18th August, 2002

Keynote: S.X. Dou, S. Soltanian, J. Horvat, X.L. Wang, A. Pan, P. Munroe, S.H. Zhou, M. Ionescu, H.K. Liu, M. Tomsic	Enhancement of the Critical Current Density and Flux Pinning of MgB ₂ Superconductor by Nanoparticle SiC Doping
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23rd International Conference on Low Temperature Physics (LT23), 20-27th August,
2002, Hiroshima, Japan

V. Pan, S. X. Dou, and H. K. Liu	Magnetic flux distribution in a superconducting core of Bi- 2223 tape
A. V. Pan, R. Höhne, and P. Esquinazi	3D-2D-like transition above B _{c2} in niobium films

1st National Conference and Exhibition on Nanotechnology, Institute of Materials
Engineering Australasia Ltd, 25-27th September 2002, Sydney, Australia

S.X. Dou (invited talk)	Control of nanostructure for enhancing the superconductor’s performance
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Seminars by Visiting Scientists

Date	Name	Institute	Talk title
31/1/02	Dr EW Collings	Laboratories for Applied Superconductivity & Magnetism, Ohio State University	Reduction and Elimination of External-Field AC Loss in MgB ₂ /Fe Wire by <i>in-situ</i> Magnetic Shielding” and “Science & Technology of MgB ₂ Materials, Strings & Applications”
20/3/2003	Prof. T. Matsushita	Kyusu Institute of Tech, Japan	Critical Current Density and Flux Pinning of HTS
20/3/2002	Prof. M. Komori	Kyusu Institute of Tech, Japan	Flywheel Energy Storage System Supported by Hybrid Magnetic Bearings with H-infinity Controller
9/5/02	Dr Shi Zhong	Leadcel Dynamic Energy Ltd, P.R. China	“Report on Technological Transfer from Lab to Industry, Leadcel Dynamic Energy Co –A new generation of VRLA batteries”
10/5/02	Dr Makunda P Das	Dept of Theoretical Physics Australian National University	“Novel Superconducting Phenomena at Interfaces”
15/5/02	Dr Y Chen	Dept Electronic Materials Eng, Australian National University	“Large Quantity Production of Carbon and Boron Nitride Nanotubes by Mechano-thermal Process”
19/11/02	Dr JZ Sun	Dept. of Materials & Physics, Monash University	Ionic liquids and polymer electrolytes
10/12/02	Dr C.Y. Zhang	Dept. Physics, Rensselaer Polytechnic Institute	Terahertz Ray Science & Technology

Equipment and Facilities

ISEM facilities contain 9 laboratories with a floor space of approx 420m² comprising modern facilities for processing and characterization of HTS and energy storage materials; materials processing and a full range of materials characterization.

The majority of these facilities were founded through 6 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 and Prof J.N. Bell, Prof. M. Wilson

Materials Processing Facilities

- Freeze Drier, Lyph-Loch 4.5, 4.5l/24h
- Spray Drier, GA-32, ~100g/h
- 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 glovebox

Thin Film Deposition Facility

- Excimer laser, ComPex301, 9W, 10Hz, 248nm
- Thin Films Deposition Chamber, 18" dia. With high vacuum system

Materials Characterisation

- DTA/TG, Setaram, 18-92, 1750°C
- XRD for Single Crystals
- TEM, J2000FX1, with EDS
- Gas absorption analyzer Nova 1000 for BET and pore size analyses
- XRD, M18XHFCu with HT 2000°C camera
- 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, 4-400K, 0-5T DC field
- PPMS, 2-400K, 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, 12K-300K
- 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

Chemical Property Characterisation

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



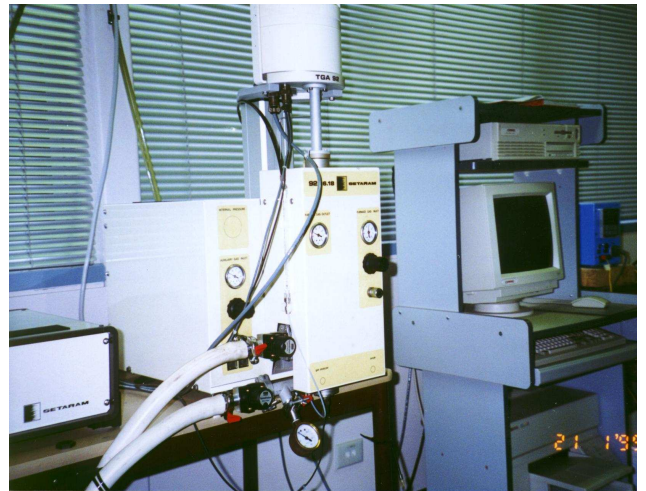
ICP-OES, Vista Simultaneous Axial Spectrometer



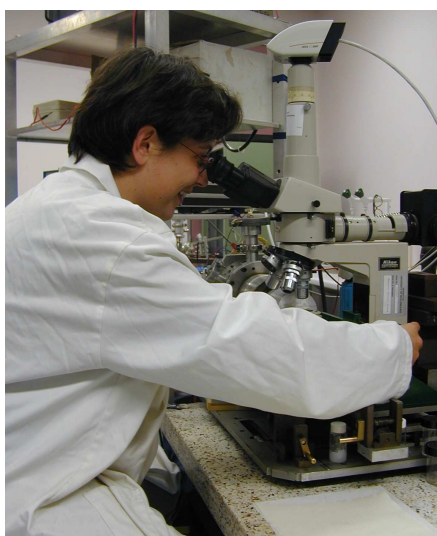
Excimer Laser Ablation System for Thin Film Deposition



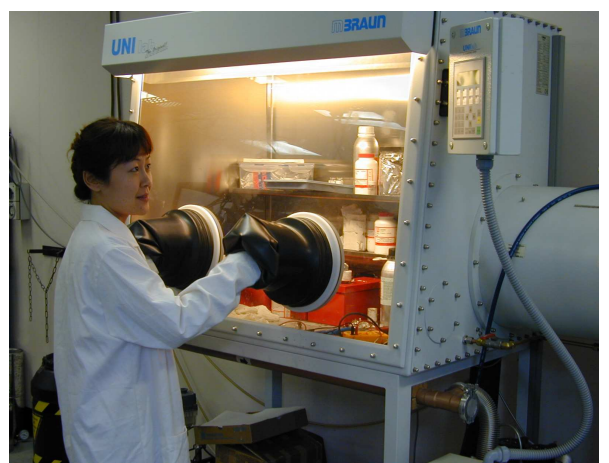
Magnetic Property Measurement System
4K-300K, 0-5T



Simultaneous DTA/TGA to 1700°C



Magneto-Optical Imaging with Cryocooler from 12K to 300K



Glovebox for Creating Oxygen and Moisture free Environment

Refereed Publications

HTS Program

- W.M. Chen, G. Li, S.S. Jiang, H.Y. Ling, P. Yao, M.J. Qin, H.K. Liu and S.X. Dou "Transmission electron microscopy evidence for phase transformation from $\text{Bi}_2\text{Sr}_2\text{CuO}_6$ to $\text{Bi}_2\text{Sr}_2\text{Ca}_2\text{Cu}_3\text{O}_{10}$ " *App. Phys. Lett.* **81**, **4**, 688-690 (2002)
- W.M. Chen, H.K. Liu, X. Fu, Y.C. Guo, D. Shi and S.X. Dou "Effect of various mechanical deformation techniques on pinning force densities in Ag/Bi-2223 tapes" *Proc. Int. Cryogenic Mat. Conf.* 16-20/7/01, Eds: B. Balachandran, D. Gruber and K.T. Hartwig, 748-754 (2002)
- Z.X. Cheng, X.J. Yi, J.R. Han, H.C. Chen, X.L. Wang, H.K. Liu, S.X. Dou, F. Song and H.C. Guo "Up-conversion luminescence of ytterbium and thulium co-doped potassium yttrium double tungstate crystal" *Crys. Res. Technol.* **37**, **12**, 1318-1324 (2002)
- S.X. Dou, A.V. Pan, S. Zhou, M. Ionescu, H.K. Liu and P.R. Munroe "Substitution-induced pinning in MgB_2 superconductor doped with SiC nano-particles" *Supercond. Sci. Technol.* **15**, 1587-1591 (2002)
- S.X. Dou, S. Soltanian, J. Horvat, X.L. Wang, S.H. Zhou, M. Ionescu, H.K. Liu, P. Munroe and M. Tomsic, "Enhancement of the critical current density and flux pinning of MgB_2 superconductor by nanoparticle SiC doping" *App. Phys. Lett.* **81**, **18**, 3419-3421 (2002)
- V.V. Flambaum, G.A. Stewart, G.J. Russell, J. Horvat and S.X. Dou "The effect of hydrogenation on the superconducting transition temperature of MgB_2 " *Physica C* **382**, 213-216 (2002)
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- J. Horvat., X.L. Wang, S. Soltanian and S.X. Dou "Improvement of critical current in MgB_2/Fe superconducting wires by a ferromagnetic sheath" *App. Phys. Lett.* **80**, **5**, 829-831 (2002)
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- A.H. Li, M. Ionescu, X.L. Wang, S.X. Dou and H. Wang "RE SrAl_2O_7 (RE=Nd and La): a new type of perovskite ceramic substrate for Bi-Sr-Ca-Cu-O superconducting thick films" *J. Alloys & Compounds* **333** 179-183 (2002)
- S. Li, O. Prabhakar, T.T. Tan, C.Q. Sun, X.L. Wang, S. Soltanian, J. Horvat and S.X. Dou "Intrinsic nanostructural domains: Possible origin of weaklinkless superconductivity in the quenched reaction product of Mg and amorphous B" *Appl Phys. Lett.* **81**, **5** 874-876 (2002)
- J. McKinnon, M. Ionescu, D. Shi and S.X. Dou "On the growth mechanisms of thin films produced by pulsed laser deposition" *Proc. Int. Cryogenic Mat. Conf.* 16-20/7/01, Eds: B. Balachandran, D. Gruber and K.T. Hartwig, 547-554 (2002)
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Solid State Physics Program

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- R.A. Lewis, X.L. Wang, S.X. Dou, N. Biskup and J.S. Brooks "Ferromagnetic resonances in polycrystalline $\text{La}_{0.8}\text{Li}_{0.2}\text{MnO}_3$ " " *Proc. Physical Phenomena at High Magnetic Fields-IV*, Santa Fe, USA 19-25/10/01, Ed: G Boebinger, Z. Fisk, L.P. Gor'kov, A. Lacerda, J.R. Schrieffer, 459-462 (2002)
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Patents

- S.X. Dou, K. Konstantinov, H.K. Liu and G.X. Wang "Fabrication of cathode materials for Li-ion batteries", Australian Innovation Patent No 2002100190 (2002)
- K. Konstantinov, S.X. Dou, H.K. Liu, G.X. Wang and S.L. Bewlay "Development of new positive compounds for lithium-ion batteries" Australian Innovation Patent No 2002100403 (2002)
- G.X. Wang, K. Konstantinov, S.X. Dou and H.K. Liu "Cathode materials for rechargeable lithium batteries and a process for production" Australian Innovation Patent No 2002100000 (2002)
- S. Zhong, K. Konstantinov, C.Wang, S.X. Dou and H.K. Liu "Method for production of spherical nickel hydroxide for rechargeable nickel-metal hydride batteries" Australian Innovation Patent No 2002100001 (2002).

Funding 2002

Australian Research Council Grants

ARC Large/Discovery Scheme Grants

S.X. Dou	Enhancement of transport J_c in magnetic field of Ag/BiPbSrCaCuO tapes by fission tracks	\$77,589	
H.K. Liu	Current limiting mechanism in Ag sheathed (Bi,Pb)SrCaCuO tapes using magneto-optical imaging and magnetic force microscopy	\$67,261	
S.X. Dou, J. Horvat	First principles for development of high temperature superconducting wires	\$222,295	
X.L. Wang	Enhancement and elucidation of flux pinning in doped Bi-Sr-Ca-Cu-O high temperature superconducting single crystals	\$61,184	
H.K. Liu	Growth, characterisation and flux pinning behaviour of doped $TiSr_2Ca_2Cu_3O_y$ and $TiSr_2CaCu_2O_y$ and high temperature superconducting single crystals	\$58,191	\$486,520

ARC Fellowship Scheme Grants

H.K. Liu	Sen. Res. Fellow, Optimisation of thermal & mechanical Processing & critical current density High T_c superconducting ag-clad Bi(Pb)SrCaCuO Tapes	\$96,817	\$96,817
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ARC Linkage Projects & Linkage APAI

S.X. Dou, M. Apperley	Investigation of Bi-2223/Ag superconductor winding for application In electrical fault current limiter	\$97,000	
H.K. Liu, D.H. Bradhurst, S. Zhong	High energy batteries for electric vehicles	\$75,000	
X.L. Wang	Fabrication of magnesium diboride (MgB_2) thick films	\$22,545	
S.X. Dou, GX. Wang	Developing new cathode materials for lithium-ion batteries using Australian mineral resources	\$83,000	
S.X. Dou, X.L. Wang, M.Ionescu	Fabrication and characterisation of magnesium diboride superconducting wires	\$110,000	
H.K. Liu, S. Zhong	Investigation of nano-materials for use in lithium rechargeable batteries	\$67,000	
R. Lewis, C. Zhang	Experimental development of thermionic cooling for domestic refrigeration	\$22,292	
G.X. Wang, H.K. Liu, S. Zhong	Solid-state rechargeable lithium batteries for telecommunication and portable electronic devices	\$74,080	
			<u>\$550,917</u>

Linkage International Awards

R.A Lewis, C. Zhang	Development of solid-state cooling chips		\$11,700	
H.K. Liu, D. Shi	Investigation of a series of metallic substrate materials suitable for developing long Y-Ba-Cu-O superconductors		\$19,396	
S.X. Dou, J. Lee	Composite cathode materials for lithium ion battery using chemical coating techniques		\$69,424	\$100,520

Systemic Infrastructure Initiative Grants

S.X. Dou et al	Nanofabrication facilities for processing of novel multiplayer materials	ARC funding	\$440,000	
		Matching funding	\$192,550	632,550

Small Grants & Indicative Near Miss Grants

J. Horvat	Magnetic shielding in MgB ₂ /Fe superconducting wires		\$9,700	
M.J. Qin	Electric losses of superconductor thin strips in perpendicular magnetic fields		\$8,600	
J.X. Jin	Novel study of HT-superconductor in a resonant electronic circuit		\$8,000	
C. Zhang	Theory and simulation of terahertz imaging		\$5,000	
G.X. Wang	Preparation of carbon nanotubes for energy storage		\$6,000	
H.K. Liu, X.L. Wang	Investigation of new superconductors: magnesium diboride (MgB ₂) compounds		\$6,000	
C. Zhang, Z. Chen, R. Lewis	Cool chips: developing on-board solid-state cooling for electronic devices		\$6,000	\$39,300

Australian Institute of Nuclear Science & Engineering

D. Marinaro/SX Dou	Special Postgraduate Award		\$5,500	
T. Silver	Thermal neutron irradiation of uranium-doped superconductors		\$1,710	
X.L. Wang	Studies of novel perovskite cobalt compounds		\$10,818	
X.L. Wang	Studies of magnetic properties of doped Y-Sr-Co-O perovskite cobalt compounds		\$27,818	
X.L. Wang	Enhancement of critical current density in newly discovered MgB ₂ superconductors using hot isostatic press and hot press techniques		\$2,300	\$48,146

Industry Grants

Metal Manufactures Ltd		\$41,000	
Lexel Battery Co Ltd		\$19,500	
Sons of Gwalia Ltd		\$30,000	
Hyper Tech Research Inc		\$20,000	
Australian Battery Technology Ltd		\$15,000	
OMG Group		\$10,000	
Alphatech International Ltd		\$6,000	
FSL Enterprises Ltd		\$5,000	\$146,500

University of Wollongong Support

ISEM Performance Indicators		\$125,745	
Faculty of Engineering funding		\$20,000	
ISEM Management Fund		\$75,000	
URC contribution		\$76,000	
Postgraduate student maintenance funds		\$29,625	
Scholarships		\$189,000	\$515,370

Total 2002 funding **\$2,625,642**

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