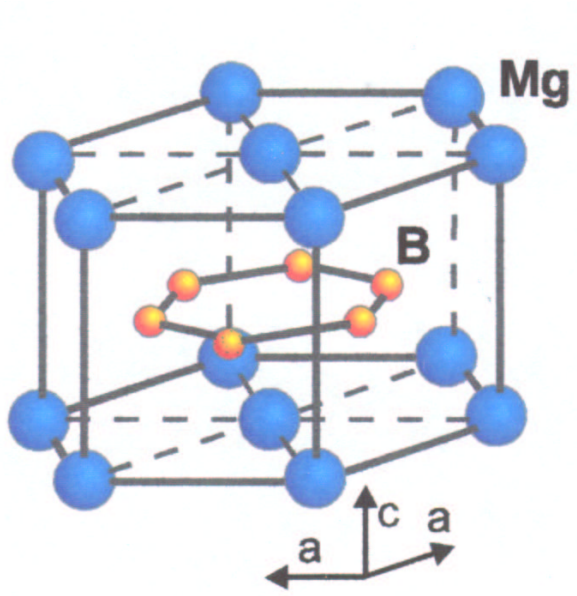
Annual Report 2001



Institute for Superconducting & Electronic Materials

University of Wollongong

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.

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Cover Picture: Newly discovered 39 K superconductor structure of MgB_2 containing graphite-type B layers separated by hexagonal close-packed layers of Mg

Contents

Director's Report

During 2001 our institute experienced solid growth in all three research programs. I would like to highlight the progress in the different aspects as follows.

Research Progress: Research progress on various ARC funded projects for the year of 2001 are reported in details in a later section. These are also highlited in the section on selected published abstracts. In the superconductivity area, the HTS group has developed a number of novel techniques for processing and fabrication of powders, bulk materials, single crystals, wires and tapes based on the newly discovered MgB_2 superconductor. This group has (a) developed a nanocrystalline fabrication technique to process superconducting wire with critical current density over 4 million A/cm^2 at 5K and record high transport current density of 54kA/cm^2 at 30K; (b) identified iron not only to be compatible with MgB_2 but also an ideally magnetic screening material for reducing the effect of external fields and ac losses; and (c) gone on to clearly demonstrate the great potential of this emerging superconductor for various practical applications. In the area of energy storage materials, significant progress has been made in synthesis of cathode materials for Li-ion batteries. Novel techniques for processing $LiCoO_2$ have been developed and the quality of this material as cathode for Li-ion battery is comparable with state-the-art products. In the area of semiconductors, thermionic cooling mechanism has shown a great promise for applications with high efficiency and energy savings. There has been excellent progress on fundamental studies of new materials such as CMR, control of nanostructures, flux dynamics and flux pinning in HTS and nanomaterials. It is clear that nanomaterials have formed a focus point for our research activities.

Education and Training of Postgraduate Students: In 2001 four postgraduate students were awarded a PhD or Masters. Dr G.X. Wang's PhD thesis was awarded the best PhD thesis by the Faculty of Engineering and he was also awarded an ARC Postdoctorial Fellowship. Dr X.L. Wang was recently awarded an ARC Postdoctorial Fellowship. Dr. X.K. Fu has been awarded the STA Fellowship at the Railway Research Institute in Japan. I welcome the six new postgraduate students enrolled for 2002. S. Bewley, C.B. Cai, Y Zhao and Z.M. Zhang were awarded APAI's, A.H. Li was awarded an APA, J.Yao was offered an ISEM scholarship and C Tao was awarded a UPA and OPRS. ISEM has established an annual Excellence award for its most outstanding postgraduate student. Mr Saied Soltanian was awarded the Postgraduate Student Excellence Award ($1000) for 2001 for his outstanding performance in research on MgB_2 materials. Mr Matthew Lindsay, Ms Zaiping Guo, Mr Krishna Uprety and Mr Benjamin Lough were awarded Postgraduate Student Merit certificates ($200) for their excellent performance in their various research areas.

Research Grant Outcomes: In 2002 round ARC grant competition, ISEM has 9 various ARC grants and an Systemic Infrastructure Initiative grant (SII) successful, totalling $3.81 million. This represents 28% of total ARC, NHMRC and SII funding of $13.2 million obtained by the University of Wollongong in 2002 round. ISEM has 2 ARC discovery projects (22% successful), 2 ARC fellowships (67% successful), 4 Linkage projects (100% successful), 2 ARC International Linkage projects and 1 International Fellowship (100% successful). ISEM has once again placed at the first place among all research units at UoW. 3 International Linkage grants at UoW are all from our institute. Our SII grant is the only one in UoW and one of 22 successful grants in all the universities.

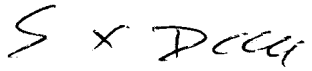
National and International Network to Improve Infrastructure and Collaboration: ISEM has established very effective co-operation with 13 institutions Australia wide, resulting in continuing successes for a fifth large RIEF grant, awarded in 2001, to install a SQUID Magnetometer and Magneto-optical Imaging system. Recently, the Department of Education, Training and Youth Affairs granted a Systemic Infrastructure Initiative grant ($1.7million over the next 3 years) on nanofabrication facilities for producing multilayer materials. These grants involved about 13 Chief Investigators and a large number of academic staff, research fellows and postgraduate students from eight institutions. Together with funding from previous ARC RIEF grants, the total funding for research infrastructure, equipment and facilities well exceeds $6m. ISEM has 13 laboratories of about 600 m^2, including advanced facilities for materials processing and characterisation. Our laboratory provides services to a

number of Australian institutions and a wide range of consultantancy work to a number of industries, including companies from New Zealand, United States of America, and Asian countries. In 2001 ISEM further extended its international collaborative network. The strong interaction between ISEM and other major centres, for example, may be evidenced by the large number of joint grants, joint publications, the continuing success in the international exchange program, invited talks to international conferences and visits to Australia by distinguished guests. Five ARC International Exchange Programs have been successfully carried out with collaborating overseas institutions.

Industries Interaction: ISEM has established longstanding collaborations with a number of industries. In 2001 ISEM further extended its collaboration to Australian mineral companies, Billiton's Queensland Nickel Ltd and Sons of Gwalia Co., and international companies Hyper Tech Inc. (USA), Alphatech International Ltd. (New Zealand), Golden Champower Ltd., and Leadcel Dynamic Energy Co., (China). In addition, existing industrial partners, Metal Manufactures (MM) Ltd, Australian Superconductors Ltd., Lexel Battery Ltd, E-mail Ltd, Australian Battery Technology Ltd and Zhuhai Taiyi Ltd are continuing their support to our research work. The enthusiastic participation and support of these industrial partners is critical to our research success.

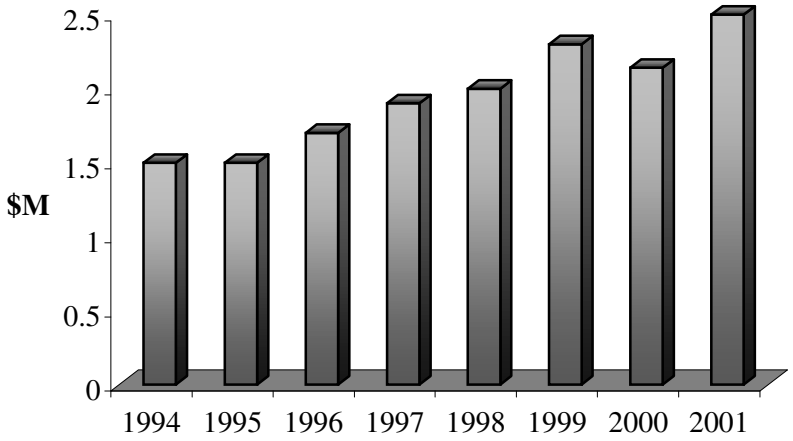
Strategy for Future Growth: In order to ensure future growth, ISEM will place emphasis on research which is in-line with the Innovation Action Plan, Backing Australia's Ability. In particular, ISEM will enhance and direct its research programme on priority research areas identified by the ARC.

- The HTS and Energy Storage Materials Programs will emphasise nanomaterials including control of nanostructures, development of new nanomaterials and multilayer materials and nanofabrication technology and characterisations.
- The Solid State Physics program will place emphasise on the photon science and technology, including laser science and applications, photonics and electronics.
- Energy storage materials programme will further improve R&D in materials fabrication technology to enhance the commercialisation of these materials.
- ISEM will jointly apply to be an ARC centre of excellence in nanomaterials.

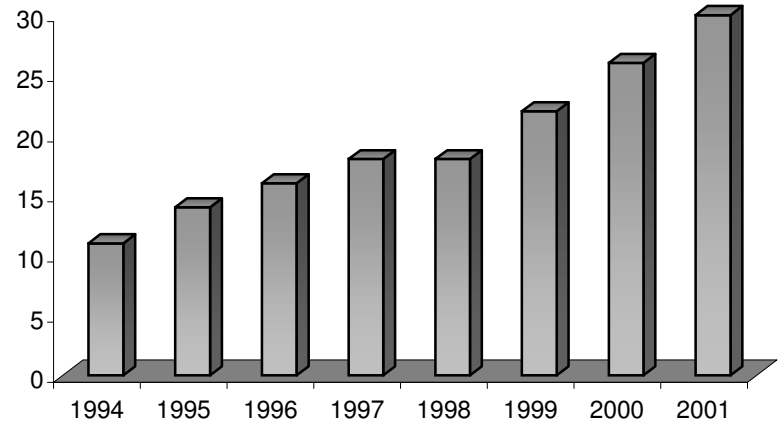


Shi Xue DOU

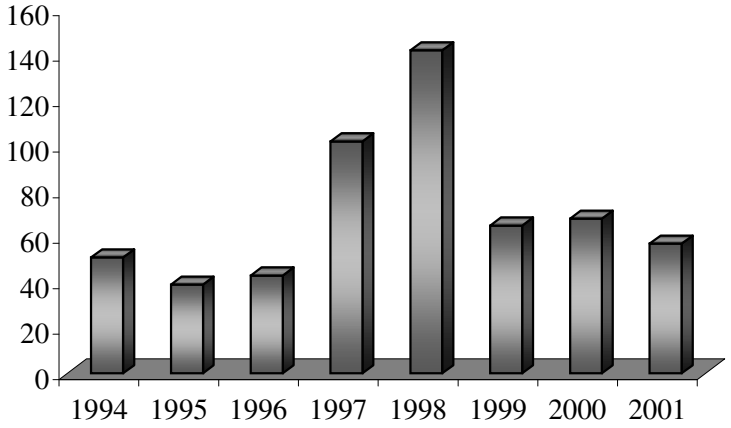
Research Grant Funds



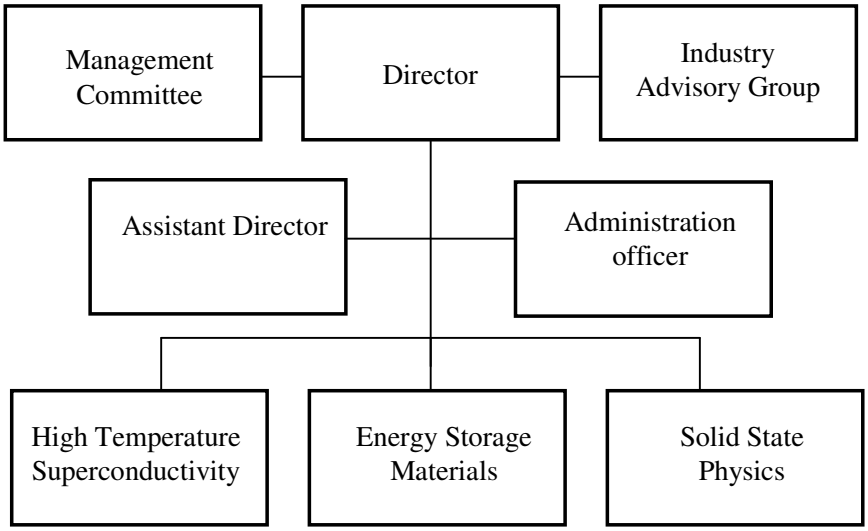
Postgraduate Student Numbers



Refereed Publications (DETYA Categories)



Management



Management Committee

Chairman:	Prof. S.X. Dou	Director, ISEM
	Prof. C. Brink	Pro Vice Chancellor, UoW
	Prof. B. Parker	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 Buchtmann	Advanced Systems Engineer	Email Limited
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
Ms K. Howison	Process Engineer	Billiton's Nickel Division, QNI Technology Ltd
Mr. R. Neale	Managing Director	Alphatech International Ltd
Mr D. Kingsnorth	Manager for Market 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, Shenzen, PR China
Mr Y.W. Zhu	Technical manager	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.

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

ARC Fellows

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

Dr. E.H. Brandt, BSc, PhD, ARC International Professorial Fellow

Dr. Y.C. Guo, BSc, MSc, PhD, ARC Postdoctoral Fellow

Prof. H.K. Liu, Dipl. For PGS, Dipl. AQC, APF

Dr. P. Majewski, ARC International Prof. Fellow

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

Dr. S. Zhong, B.Eng., M.Eng., PhD, ARC Postdoctoral Fellow

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

Dr. W. Xu, BSc, MSc, PhD, ARC Research Fellow

Administration Officer

Ms. Babs Allen

Research Staff

Mr. B. Chao, BSc, MSc

Dr. J. Horvat, BSc, PhD

Dr. K. Konstantinov, MSc, PhD

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

Dr. T. Silver, BSc, PhD

Dr. G. Walters, 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. W.M. Chen, Nanjing Uni, PR China

Prof. E.W. Collings, Ohio State University

Ms Ling Yuan, Lexel Battery Ltd

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

Dr. S. Kennedy, ANSTO

Postgraduate Students

Current

High Temperature Superconductivity Group

PhD	Thesis Title	Supervisors
CB Cai	Fabrication and Characterisation of MgB_2 Thin Films and Coated Conductors	SX Dou, M Ionescu
F Darmann	Characterisation of Melt-texture Y-123 Materials	SX Dou, T Beales, C Cook
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, R A 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	Novel substrates for Bi-Sr-Ca-Cu-O superconducting	M Ionescu, SX Dou
G Li	Numerical Analysis on Electromagnetic Behaviour of High Tc 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
DQ Shi	Investigation of Buffer Layer for Y-123 Coated Conductor Using Laser Ablation	M Ionescu, SX Dou
S Soltanian	Characterisation of CMR Materials & MgB_2	SX Dou, XL Wang
K Uprety	Vortex properties of Bi-HTS	SX Dou, J Horvat
SH Zhou	Density Evaluation During Processing of Bi-2223/Ag Tape	HK Liu, A Pan

Masters		
M Farhoudi	AC Loss of Ag/Bi-2223 Tape in AC Field	J Horvat, SX Dou
M Ling	Mechanism of Outgrowth in Multifilament Bi-2223 Tape	SX Dou, YC Guo
E Sotirova	Investigation of Colossal Magnetoresistance Materials	HK Liu, XL Wang
ZM Zhang	Alloy Sheathed Bi-2223 HTS Tapes for Current Leads	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, S Zhong
C Wang	Investigation of Positive Electrodes for Ni-MH Batteries	HK Liu, S Zhong
GX Wang	Investigation on Electrode Materials for Lithium Ion Batteries	HK Liu, SX Dou
JZ Wang	Bipolar Electrode Materials and Design for Electric Vehicles	HK Liu, D Bradhurst
Masters		
J Yao	Nanocarbon tube for anode materials of Li-ion batteries	HK Liu, JH Ahn

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
Masters		
H Ta	Electronic Properties of Modulated Two Dimensional Semiconductors	C Zhang
S Lee	Multilayer thermionic cooling in semiconductor heterostructures	R.A. Lewis, C. Zhang

Completions

PhD Name & Thesis Title	Awarded	Position	When Appointed
M Apperley The Fabrication of High Tc Superconductor Wire	1992	Chief Technologist Australian Superconductors	1993
R Baker	Zeeman and Piezospectroscopy of Antimony and Aluminum in Germanium	P Fisher, R Vickers	
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	1999
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
X.K. Fu Superconducting current leads using Bi-HTS	2002	STA Fellow Japan Railway Research Institute	2002
YC Guo Investigation of Silver-clad $(Bi,Pb)_2Sr_2Ca_2Cu_3O_{10-x}$ Superconducting Tapes	1994	STA Fellow Nat. Res. Inst. Of Metals, Japan ARC Postdoctoral Fellow ISEM, University of Wollongong	1997 1998
RJ Heron Far-infrared Studies of Semiconductors in Large Magnetic Fields	1998	Postdoctoral Fellow SUNY, Buffalo, USA	1997
QY Hu Fabrication and Enhancement of Critical Currents of Silver Sheathed $Bi,Pb_2Sr_2Ca_3Cu_3O_{10}$ Tapes	1996	Research Fellow Florida State University, USAResearch Scientist Argonne National Lab., USA	1997 1999
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 $(Bi,Pb)_2Sr_2Ca_2Cu_3O_{10+x}$/Ag High T_c superconductors and their Applications in an Electrical Fault Current Limiter and an Electronic High Voltage Generator	1998	Research Fellow ISEM, University of Wollongong ARC, PDF ISEM, University of Wollongong	1997 2000
M Lerch Optical & Electrical Studies of Resonant Tunneling Heterostructure	1998	Research Fellow Medical Physics	1999

PhD Name & Thesis Title	Awarded	Position	When Appointed
M Ling Mechanism of Outgrowth in Multifilament Bi-2223 tape	2001		
BL Luan Investigations on Ti_2Ni Hydrogen Storage Alloy Electrode for Rechargeable Nickel-Metal Hydride Batteries	1997	NRC Fellow National Research Council of Canada	1997
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 Theremodynamic 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	2000
G Takacs Spectroscopy Of The Effect Of Strains And Magnetic Field On Shallow Acceptor Levels In Germanium	1999	Lab Manager 2nd Year Physics Lab	1999
N. Vo Design And Characterisation Of HTS Coils	1997	Research Fellow Los Alamos Nat. Lab, USA Research Staff Intermagnetics General Co., USA	1999 1998
G.X. 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 $(Bi,Pb)_2Sr_2Ca_2Cu_3O_{10}$ Tapes By Powder-In-Tube Technique	1998	R&D Manager Nordic Superconductor Tech. Denmark	1997
XL Wang Spiral Growth, Flux Pinning And Peak Effect In Doped And Pure Bi-2212 HTS Single Crystal	2000	Research Fellow ISEM, University of Wollongong	1999
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 University of New South Wales, Australia	1996
J Yau Ag/Bi-2223 Tape Processing and Mechanical Properties	1994	Assistant Professor Chinese Hong Kong University	1995

PhD Name & Thesis Title	Awarded	Position	When Appointed
M Yavus Powder Processing of Bi-Pb-Sr-Ca-Cu-O Superconducting Materials	1997	Ass. Professor Texas A&M University, Texas USA Ass. Research Professor Tohoku University, Sendai, Japan	2000 1997
B Zeimetz High Temperature Superconducting Tapes & Current Leads	1998	Research Fellow Cambridge Univ., U.K.	1999
S Zhong Investigation on Lead-Calcium-Tin-Aluminium Grid Alloys for Valve-Regulated Lead-Acid batteries	1998	ARC Postdoc. Fellow ISEM, University of Wollongong	1997
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
JX Jin $(Bi,Pb)_2Sr_2Ca_2Cu_3O_{10+x}$/Ag High T_c Superconductors and their Applications in an Electrical Fault Current Limiter and an Electronic High Voltage Generator	1994	Research Fellow ISEM, University of Wollongong ARC, PDF ISEM, University of Wollongong	1997 2000
E. Sotirova Investigation of Colossal Magnetoresistance Materials	2001		
K Uprety Vortex Properties of Bi-HTS	1999	PhD Candidate ISEM, University of Wollongong	2000
JZ Wang Investigations on Anode Materials For Rechargeable Lithium-Ion Batteries	1999	PhD Candidate ISEM, University of Wollongong	2000
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	Dr. S. Kennedy, Dr. M. James, Dr M. Reinhard
Australian National University, Canberra	Dr. M. Das
CSIRO Division of Energy	Dr. L. Lam, Dr. D. Rand
University of Sydney	Dr. S. Ringer
Curtin University of Technology	A/Prof. J Low
Macquarie University	A/Prof. E. Goldys
University of Technology, Sydney	Prof. G. Smith
Monash University	Dr. Y.B. Cheng, Krishnamurthy
University of Melbourne	Prof. D. Jamieson
UNSW Schools of Physics, Elec. & Chemical Eng.	Dr. R. Ramer, Prof. M.S. Kazakos
James Cook University	Prof. J. Mazierska
University of Queensland	Prof. G.Q.M. Lu

International

Atomic Institute of Austrian Universities, Vienna, Austria	Prof. H.W. Weber
Brookhaven National Lab	Dr. X.Q. Yang
Dalhousie University, Canada	Prof. J. Dahn
Harbin Institute of Technology, PRC	Prof. J.S. Wang
Houston University, USA	Prof. R. Weinstein
Institute for Metal Physics, Kiev, Ukraine	Prof. V. Pan
Ludwig Boltzmann Institut für Festkörperphysik, University of Vienna, Austria.	Dr. W. Lang
Max-Planck-Institut für Metalloforshung, Germany	Dr. E.H. Brandt, Dr. P. Majewski
Max-Planck-Institut für Solid State Physics, Germany	Prof. U. Habermeier
Nankai University, PRC	Prof. J. Chen, Prof. Y.H. Tang
Nanjing University	Prof. S.Y. Ding, Prof. W.M. Chen
Nanyang Technological University	Prof. S. Li
National Andong University	Prof. J.H. Ahn
Northeatern University, Shenyang, PRC	Prof. Y.C. Zhai
Ohio State University, Columbus, OH, USA	Dr. E.W. Collings, Dr. M. Sumption
Osaka National Reseach Institute, Japan	Dr. T. Sakai
University of Auckland	Prof. W. Gao
University of Cincinnati	Prof. D. Shi
University of Wisconsin	Prof. D. Larbalestier, Dr. A. Polyanskii
University of Zagreb, Zagreb, Croatia	Prof. E. Babic, I. Kusevic
Yamagata University, Japan	Dr. S. Kambe, Prof. Ohshima
Kyushu Institute of Technology	Prof. T. Masushita
Institute of Physics, Chinese Academy	Prof H.H. Wen

Progress Reports for Projects funded by the Australian Research Council

1. Progress Reports on ARC Large/Discovery Projects

1.1 *Investigation of growth mechanism and flux pinning in spiral grown $Bi_2Sr_2CaCu_2O_y$ and $Bi_2Sr_2Ca_2Cu_3O_y$ monocrystals*

Funded:	1999	2000	2001
Project ID:			
Chief Investigator:	S.X. Dou		
Assoc. Investigators:	E.W. Collings, V.P. Pan, J. Horvat		
Research Fellow:	X.L. Wang		

The aim of the proposed research is to investigate the newly discovered spiral growth mechanism and the influence of spirals and associated defects on flux pinning characteristics of doped and un-doped $Bi_2Sr_2CaCu_2O_y$ and $Bi_2Sr_2Ca_2Cu_3O_y$ monocrystals. Recently, great attention has been paid to heavily lead doped Bi2212 single crystals, where a strong improvement of vortex pinning has been reported by our group. In pure Bi2212 single crystals, most of the $H-T$ vortex phase diagram is dominated by the presence of the vortex liquid phase. This is due to their large anisotropy, which is responsible for weak inter-layer 2D pancake vortex coupling. The effects of thermal excitations on these 2D pancake vortices are very strong, as compared to 3D vortex lines, so that 2D vortices can be easily depinned. In order to reduce thermal fluctuations of the 2D vortices, a strong inter-layer coupling between them is desirable. It was pointed out that an observed increase in vortex pinning due to columnar defects in Bi2212 single crystals, introduced by heavy ion irradiation, was caused by the Josephson coupling between 2D pancake vortices. Thus coupled vortices formed 3D vortex lines. In one of our papers, we have interpreted the strong pinning in heavily Pb doped single crystal in terms of this improved c axis conductivity where an inter-layer Josephson coupling of 2D vortices converts 2D vortices into 3D vortex lines. The main result of the paper was a large shift of the crossover temperature, T_{CR} = 35K, a temperature separating two different pinning regimes in the heavily Pb doped single crystal for a field that was within the secondary peak in its magnetic hysteresis loop. For pure Bi2212, $T_{CR} = 19\text{K}$.

We have also investigated the magnetic field $H_{ODT}(T)$ where an order-disorder transition of the vortex lattice in high- T_c superconductors occurs, by measurements of the magnetization M(H) in 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 on the low-field-side of this peak. $H_{ODT}(T)$ is suggested to lie close to $H_{infl}(T)$. In $Bi_{2.1}Sr_{1.9}Ca(Cu_{1-y}Fe_y)_2O_{8+\delta}$ single crystals with Fe concentration y = 0, 0.005, 0.016 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 $H_{ODT}(T)$ that 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 normalised relaxation rate S(H) is observed close to $H_{infl}(T)$ 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 $H_{ODT}(T)$ in heavily Pb doped Bi2212 crystals is related to the enhanced c axis conductivity caused by the Pb sitting between the CuO_2 layers and causing 3D vortex lines, while in Fe doped Bi2212 crystals the defects sit on the CuO_2 planes and thus do not enhance the coupling between pancake vortices.

1.2 *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		

The objective of this project is to enhance flux pinning by using a combination of stabile 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 critical current density J_c in magnetic fields and minimized anisotropy of HTS compounds. We also intend to devise doping and irradiation techniques to reduce radioactivity to a level acceptable for handling. Preliminary work resulted in the identification of two uranium compounds more compatible with Bi-2223 than uranium oxide, $UCa_{2-x}Sr_xO_y$ and $UCa_{3-x}Sr_xO_y$ (mentioned in the project proposal) and later $Bi_2Sr_2Ca_2Cu_3$. Uranium oxide reacts with BSCCO superconductors to form other compounds, degrading J_c. The new compounds are stabile and cause no reduction in J_c at levels below 1%. Bi-2223/Ag tapes have been made with the new compounds and studied.

The preliminary work was done using small amounts of depleted uranium with a view to increasing chemical compatibility. We are now at the stage where it is necessary to move on to natural and depleted uranium and are thus subject to new and more stringent regulatory and safety requirements than before. We have obtained a permit (PN149) from the Australian Safeguards and Non-proliferation Office) allowing us to possess larger quantities of natural and enriched uranium. We have acquired natural and 93% enriched UO_2 from ANSTO. We have also had to satisfy licensing requirements for students and staff to work with the uranium compounds and irradiated tapes and to construct a dedicated laboratory for the work. This work is now complete. A controlled atmosphere glove box was purchased from Labconco and furnished with filters, a press and a balance to allow safe powder handling and protection of samples from water vapor and oxygen. We have acquired a source of BSCCO precursor chemicals and expect to begin work on producing more compounds in the near future.

The new superconductor MgB_2 was discovered during the course of 2001, and ISEM has been involved in producing it and studying it in the form of pellets and iron clad tapes. Flux pinning was slightly enhanced by simply irradiating the MgB_2 with thermal neutrons. This is due to a nuclear reaction in which boron-10 (comprising 20% of natural boron) absorbs a neutron and is transmuted to ^7Li, releasing an alpha particle. We have found that doping MgB_2 with 2.5% (compound %) UO_2 or less produces good quality samples, with no degradation of J_c at zero field and (for 2.5% doping) only moderate degradation at higher magnetic fields. We have recently produced highly dense MgB_2 samples made of boron-11 (with a very small neutron capture cross-section) and doped with 1% (5.5 wt %) highly enriched UO_2. These samples will be characterized and sent to ANSTO for irradiation, in the hopes that the U/n method will produce substantial improvements in flux pinning and J_c. The U/n method is very promising for this material because ^{11}B is relatively cheap and the iron cladding used for tapes does not readily absorb thermal neutrons, so that the problems with highly radioactive ^{110}Ag due to the silver cladding of BSCCO tapes do not occur.

1.3 Cryogenic deformation and High T_c phase formation-partial decomposition of superconducting tapes

Funded:	1999	2000	2001
Project ID:	A89905277		
Chief Investigator:	H.K. Liu		
Assoc. Investigators:	S.X. Dou & B. Zeimetz		
Research Fellows:	M.J. Qin, A. Pan		

Investigation of mechanical deformation effects on the phase transformation process: The mechanical deformation effects on the phase transformation process have been investigated in detail for BSCCO tapes processed via cryogenic and room temperature pressing. The results showed that a decrease is seen for both processes and that each process has a zone which is low in Bi2223. However, the minimum phase zone shifts to lower deformation ratios in the cryogenic pressed samples. For the room temperature pressed samples the zone occurred between a 50-60% thickness reduction range while this zone occurred between 40-50% thickness reduction range in cryogenic pressed samples. The cryogenic pressed samples showed the best transformation characteristics, having a better Bi2223 phase content over most of the deformation ratios investigated. These results were explained by assuming that there were only two competing mechanisms: new phase nucleation and re-crystallization. The low Bi2223 phase zone occurred because re-crystallization of the Bi2212 phase took place. It was suggested that crystallization was favoured due to an increase in the surface energy, while phase transformation was initially favoured due to the chemical potential and subsequently by the increase in internal energy of the system. Although a mechanism for the phase transformation process could not be clearly defined, the effect of mechanical deformation was clearly highlighted.

Study of the texture of Bi2223 superconducting tapes by Electron backscattered diffraction: Electron backscattered diffraction was used to analyze the texture of Bi2223 superconducting tapes fabricated by the powder-in-tube technique. From the orientation of the Bi2223 crystals, angle-axis pair, Rodrigues-Frank vectors and orientation/misorientaion distribution were obtained and plotted. The micro-texture and meso-texture were characterized based on these plots. It was shown that a high degree of c-axis texturing was present in the microtexture of the tapes and weak a/b axis texture exists in the tapes. About 42% of the grain boundaries have a misorientation angle of less than 5^O while 20% of the grains have a misorientation angle between 5^O to 10^O. The majority of c-axis tilt boundaries were low angle grain boundaries while high angle boundaries of up to about 45^O, were shown to be c-axis rotation boundaries. It is believed that the majority of the grain boundaries produced in Bi2223 tapes are strongly coupled, with about 20% occurring in the transition region.

Investigation of mechanical deformation effects on the grain alignment: The intrinsic grain alignment mechanisms of the cryogenically pressed and room temperature pressed Bi-Sr-Ca-Cu-O tapes were found to be different. The cryogenically pressed tapes showed a step-like increase in grain alignment at approximately 30% deformation, while the increase in grain alignment for the room temperature pressed tapes was gradual. The results indicate that the behavior is reproducible and independent of annealing time and therefore, intrinsic to the deformation steps of each process. The effects of deformation on the alignment are suggested to occur due to two factors: (1) the point at which fracturing of the grains occurs and (2) rotation or movement of these grains into the preferred alignment. The differences observed between the two processes are due to the combined effects of these two factors. The significance of this study is that better grain alignment can be achieved in cryogenically pressed tapes at low deformation ratios.

1.4 *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		
Partner Investigator:	A. Polyanskii		
Assoc. Investigator:	J. Horvat, D. Larbelastier		
Research Fellow:	A. Pan, M.J. Qin		

Magneto-optical imaging has been used for study Ag/Bi-2223 tapes processed using flat rolling, sandwich rolling, and pressing methods for the intermediate mechanical deformation in powder-in-tube process through the collaboration with Dr. A. Polyaniskii in USA. The results show that not only the density of the microcracks but also their distribution affect J_c. Rolled tapes have a higher density of microcracks than pressed tapes. Although the flat rolled tape and sandwich rolled tape have the same level density of microcracks at the same reduction, the cracks in the former are more in the transverse direction than in the latter. In all three cases, J_c reaches a maximum value at an optimal reduction rate.

A systematical ac susceptibility measurement on an MgB_2 bulk sample was performed. The ac susceptibilities as a function of temperature at different temperatures, DC magnetic fields, ac field frequencies and ac field amplitudes show similar features as those of the high temperature superconductors. From the measurements we demonstrate that flux creep is a prominent phenomenon in this new material and that the flux creep activation energy is a nonlinear function of the current density $U(J) \propto j^{-0.2}$, indicating a non-logarithmic relaxation of the current density in this material. The dependence of the activation energy on the magnetic field is determined to be a power law $U(B) \propto B^{-1.33}$, showing a steep decline in the activation energy with the magnetic field, which accounts for the steep drop in the critical current density with magnetic field observed in MgB_2. The irreversibility field is also found to be rather low; therefore, the pinning properties of this material will need to be enhanced for practical applications.

In order to study the underlying pinning mechanism governing the critical current density in the new superconductor MgB_2, we measured the hysteresis loops of an MgB_2 bulk sample at different temperatures. The field dependent critical current density $j_c(B)$ was then obtained using the Bean critical state model. 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.

A low-temperature MO imaging technique has been set up at the Institute for Superconducting and Electronic Materials using a special home-built optical cryostat. Low temperatures in the cryostat are obtained with a help of a cryo-cooler capable of reaching a temperature at a sample under test as low as 19 K. This is sufficient for magneto-optical investigation not only of the high-T_c cuprate samples having their transition temperatures around 100 K, but also of recently discovered MgB_2 superconducting samples with the transition temperature of about 40 K. The cryostat has been designed to provide transport currents to the sample as high as 60 A, which is important for high transport performance superconducting samples being at low temperatures.

1.5 *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:	A10012023		
Chief Investigator:	H.K. Liu		
Assoc. Investigator:	M. Ionescu & X.L. Wang		
Research Fellow:	Z.X. Cheng		

Synthesis of ceramic powders as precursors: As pre-synthesised powders of TlSr-1212 and TlSr-1223 are essential for the success of crystal growth, we have synthesized ceramics with a high content of $TlSr_2CaCu_2O_y$ and $TlSr_2Ca_2Cu_3O_y$ phase. As $TlSr_2CaCu_2O_y$ is difficult to obtain the single phase, we have introduced Pb to partially substitute for Tl. Appropriate amounts of CuO, $CaCO_3$ and/or $BaCO_3$ were mixed and sintered at 900 ^oC for 24 h. Tl_2O_3 or Tl_2O_3 plus PbO with an atomic ratio of Tl:Pb = 6:5 were mixed with Sr/Ba-Ca-Cu-O, then pressed into pellets, sealed with gold foil and sintered at 960 ^oC for 10 h in O_2, re-ground, pressed into pellets and re-sintered at 960 ^oC for 5 h in O_2, then annealed at 880 ^oC for 30 h in O_2. Nearly single 1223 phase was identified using X-ray powder diffraction.

Crystal growth: The self flux method was adopted for the single crystal growth. Before crystal growth, differential thermal analysis (DTA) and thermo-gravimetric analysis were employed on ceramic 1223 and on on mixtures of ceramic powders of 1223 plus flux (Tl_2O_3 and CuO) with appropriate amounts of each. The measurement of the DTA curves was carried out both in O_2 and in air.
The crystals were grown using a temperature gradient technique. The Tl-1223 ceramics were ground well and mixed with fluxes of Tl_2O_3 and CuO. These powders were then packaged into an Al_2O_3 crucible and sealed by gold foil. The crystal growth was carried out in a horizontal furnace with a large temperature gradient. The furnace temperature was first raised to 1000 ^oC with a fast heating rate of 400 ^oC/h, held there for 0.5 h, then lowered to 900 ^oC with a cooling rate of 20 ^oC/h, held at 900 ^oC for 5 h and finally furnace cooled down to room temperature by switching off the power of the furnace.

Crystal morphologies: Most of the crystals investigated by optical microscopy and scanning electron microscopy have at least one flat plane. The crystals show a rectangular shape, which is in agreement with the tetragonal crystal structure of the 1223 phase. Some dark brown particles were found on the surface of some crystals. These contaminations were determined to be Tl-Cu oxide, which obviously comes from the flux, indicating the crystals were grown surrounded by fluxes of Tl-Cu-O. A common feature of the crystal surface morphologies is their layer by layer growth pattern.

The flat surface of the Tl-1223 crystals corresponds to the (a-b) plane as determined by X-ray diffraction, i.e. the growth direction for each layer is along the c-axis. In (h0l) precession photographs orientation misfits up 5^o were found for some crystals.

The thickness along the c-axis is not as thin as in BiSrCaCuO crystals. The ratio of the thickness along c to the a or b dimension is higher then 0.3. It is not easy to cleave a very thin crystal along its a-b plane. The morphology of the Tl-1223 single crystal seems like that of YBCO single crystals. The growth rate of Tl-1223 crystals along the c-axis is much higher than that of BISrCaCuO crystals.

2. Progress Report on ARC Fellowships

2.1 *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				

To understand effects of cryogenic deformation on critical current density in Bi-tapes: A cryogenic pressing at 77 K, instead of the normal room temperature pressing (hereafter referred to as normal pressing) between sintering steps, has been applied to the fabrication of Ag-Mg alloy sheathed Bi-2223 37-filament tapes. The intrinsic grain alignment mechanisms of cryogenically pressed and room temperature pressed Bi-Sr-Ca-Cu-O tapes were found to be different. Cryogenically pressed tapes showed a step-like increase in grain alignment at approx. 30% deformation, while the increase in grain alignment for room temperature pressed tapes was gradual.

Investigate effects of oxygen partial pressure on processing conditions and phase transformation in Ag/Bi-2223 tapes: The effect of oxygen partial pressure on processing conditions and phase transformation in Ag/Bi-2223 tapes was investigated using a two-step annealing process at the final thermal cycle of the powder-in-tube process. It was found that the temperature window for processing was widened and volume fraction of the Bi-2223 in the tape increased under low oxygen partial pressure. Using an atmosphere of N_2 the highest Bi-2223 volume fraction appeared at 830^{o}C (first sintering and second sintering) and 785~805^{o}C (final annealing) in a N_2-7.5% O_2 atmosphere. The samples annealed in N_2-7.5% O_2 retained their J_c values well over a wide annealing temperature range of 785~805^{o}C with only 10% deviation from the highest value. In contrast, for the same level of J_c retention using conventional methods, the temperature window would be narrowed down to half of this range. Results demonstrated that heat treatments in a N_2-7.5% O_2 atmosphere are advantageous for processing Bi-2223/Ag tapes on a large scale, as there is less demand on temperature control. An intermediate cold pressing prior to the second thermal cycle also played an important role in improving J_c as part of the two-step thermal cycle process. The J_c values of pressed tapes were almost four times larger than for tapes without intermediate pressing, due to elimination of residual pores as well as improved grain alignment of Bi-2223. The highest J_c was 45,700 A/cm^2 when annealing was done at 800 ^{o}C, which is higher than that of tape annealed in air under the optimal two-step sintering process, i.e., at 840^{o}C (first sintering and second sintering) and 820^{o}C (final annealing). Enhanced J_c for tapes annealed in 7.5% O_2 is thought to be attributable to higher volume fraction of Bi-2223. It is observed that large difference in J_c between the quenched and subsequently annealed tapes provides evidence that the amorphous phase has more detrimental effects on J_c than other impurity phases. For the tapes subsequently annealed during the second cycle, most of the amorphous phase is converted to Bi-2223, hence enhancing J_c. However, if a small amount of the residual amorphous layer still exists even after the second cycle annealing, this might lead to a large decrease in J_c, even though XRD shows very pure Bi-2223 phase. This indicates that proper conversion of liquid phase in the tape to Bi-2223 is vitally important to improve J_c.

Effects of different intermediate deformation techniques (i.e., pressing, rolling and sandwich rolling) on the microstructure, cracking and electrical properties were investigated and compared. SEM images suggest that the sandwich rolling method results in tapes with higher density, better grain alignment, less cracking and more homogeneous filaments. T_c and J_c were measured for filaments extracted from center and edge positions of the tape. It is found that T_c and J_c values are higher for filaments extracted from the center than from the edge positions of the tape; T_c variation from center to edge is smaller in the sandwich rolled tape than in the normal rolled tape; J_c for a center filament is much higher than for edge filaments. This is consistent with the microstructure of the tape that the center filaments have a higher density, better grain alignment.

2.2 New Manufacturing Process for Long Length HighTemperature Superconductors

Funded:	1999	2000	2001
Project ID:	F89700795		
Chief Investigator:	Y.C. Guo		

The main objectives of the APD project are: (i) to develop 'defined phase balance' superconductor precursor powders (year 1 task), (ii) to investigate the effect of silver alloy sheaths on the properties of Bi-2223 tapes (year 2 task), and (iii) to develop a "continuous tube forming/filling" (CTFF) technique for the continuous fabrication of long Bi-2223/Ag tapes (year 3 task).

Bi-2223 precursor powders were fabricated by using various techniques including solid-state reaction, thermal decomposition, spray drying, freeze drying, co-precipitation, and spray pyrolysis. The variously prepared powders were characterised in terms of size, morphology, phases, melting temperature and composition. These powders were used to fabricate Bi-2223/Ag tapes, and their effects on the properties of the tapes were studied. It was found that the form of Pb in the powders, not the preparation methods, determines the properties of the powders. If Pb is largely incorporated into Bi-2212 phase, rather than in the form of Ca_2PbO_4, the powders will have a higher melting temperature. Consequently, the tapes made from the powders can be sintered at higher temperature and form Bi-2223 phase more quickly and completely. Based on these findings, 'defined phase balance' powders, in which most Pb is incorporated into (Bi,Pb)-2212 phase, with only a small amount of Pb in the form of Ca_2PbO_4, were fabricated.

A series of silver alloys including AgCu, AgAl, AgNi, AgTi, AgMgTi and AgMgNi, were prepared and used to fabricate Bi-2223/alloy tapes. The mechanical strength and workability of the alloy sheaths were investigated. It was found that the sequence of the alloys' hardness from high to low is AgNiMg, AgNi, AgTiMg, AgTi, AgAl, AgCu and Ag. The sequence of the alloys' workability from high to low is Ag, AgCu, AgTiMg, AgTi, AgNiMg, AgAl and AgNi. The effects of alloys on Bi-2223 phase formation, T_c and J_c were investigated. The detrimental effect on Bi-2223 formation from high to low was found to be AgTi, AgTiMg, AlNiMg, AgAl, AgCu, and Ag. The Bi-2223 fraction in tapes made of first four alloys was <50% after heat treatment and in the last two sheathed tapes was >90%. While the effect of alloys on T_c was insignificant (except for AgTi), J_c was lowered by all alloys, particularly in the cases of AgTi, AgTiMg, AgAl and AgAlMg.

To achieve high mechanical strength, but avoid the detrimental effects, hybrid Ag-alloy tapes were produced, in which pure silver was used for the first packing and alloys were used for the second packing, forming alloy/Ag/Bi-2223 composite tapes. In this configuration, the inner Ag sheath prevented the reaction between alloy and Bi-2223 phase and hence avoided the detrimental effects of alloys on the superconductors. At the same time, the outer alloy sheath enhanced the overall strength of tapes. Results confirmed that this configuration works very well. More silver alloys were prepared and investigated in a search for alloys which enhance the tape's mechanical strength, but have little detrimental effect. Among the alloys investigated, Ag-Sb and Ag-Mg were found to be promising, having little effect on the Bi-2223 formation, T_c and J_c. These alloys can be used for both inner and outer sheaths of the tapes.

Some Bi-2223/Ag tapes have been fabricated by using the "continuous tube forming/filling" technique. More experiments are planned to optimise the processing and heat treatment parameters of this technique.

3. Progress Report on SPIRT/Linkage Programs

3.1 *Effective Transverse Matrix Resistivity of Multifilamentary Bi:HTSC/Ag Tapes in Response to Variation of Strand Architecture and Processing Method*

Funded:	1999	2000	2001
Project ID:	A69922488		
Chief Investigator:	S.X. Dou		
Partner. Investigator:	TP Beales,E.W. Collings		
Postgrad. Student:	F. Darmann		
Industry Partner:	Metal Manufactures Ltd,		
Research Fellow:	J. Horvat		

The project is aimed at lowering the coupling loss in multifilamentary superconducting tapes by elucidating the influence of the filament structure and shape factor on the loss. The coupling loss occurs as currents are pushed from superconducting filaments into the silver sheath, flowing between the neighbouring filaments. The coupling loss is the major component in the total AC loss in the tapes, and its control is an essential step in production of superconducting tapes for low-loss AC applications.

Measurements of the AC loss were performed on the tapes for which silver alloys were used as the sheath material. This was one of the proposed routes to lower the coupling loss. However, surprisingly, no significant decrease of the loss was obtained with the alloying. It turned out that the superconducting filaments in the tapes were bridged, which was a common problem in these materials. The bridging effectively precluded the measurements of the effect of the filament architecture and matrix resistivity on the coupling loss.

Bi2223/Ag tapes were re-designed and after a significant effort, tapes without bridging were obtained. These tapes were used for measuring the coupling loss and influence of the shape factor on the loss. The measurements showed a surprisingly small coupling loss in these tapes, much smaller than the loss expected theoretically, by taking into account the matrix resistivity. It was shown that this occurred because the coupling loss was limited to a small volume in close proximity to the neighbouring filaments. This points the way for lowering the coupling loss: filament architecture with the minimum volume occupied by the coupling currents between the filaments. Numerical modelling is underway, which will help in the design of such filament architecture.

All these measurements were performed by a magnetic method. A new experimental set-up has been installed, which can measure the AC loss directly, by a calorimetric method. This is achieved by measuring the evaporation rate of a liquid nitrogen bath for the superconducting tapes. This set-up is being used for measuring the loss in the superconducting coils produced from the Bi2223/Ag tapes, giving direct measurements of the loss for the tapes whose optimised filament architecture will have lowered the coupling loss.

Recent discovery of the new MgB_2 superconductor has set new goals in lowering the AC loss in the superconductors, putting new challenges in the framework of this project. This superconductor is commonly produced in the form of iron-sheathed wires. We have shown that the iron sheath can have multiple benefits in reducing the AC loss in the wires. Through magnetic screening, it can almost eliminate the AC loss in fields up to 0.2 T. However, even beyond this field, there is a substantial reduction of the AC loss, currently by about a factor 4. The latter may be an effect of an interaction between the superconductor and the iron sheath, and it may show new ways for lowering the AC loss.

3.2 *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		

The research objective is to study $(Bi,Pb)_2Sr_2Ca_2Cu_3O_{10+x}$ Ag-clad wire for use as a dc bias winding for an inductive fault current limiter (FCL). The HTS FCL project has reached the stage where the final assemblage of the device with the HTS system is being constructed. The HTS FCL project work carried out during the second year of operation is summarized as follows. The HTS dc bias winding design has been finalized based on the available HTS wire and its performance characteristics. HTS coil has been tested and the results analysed. The HTS coil winding techniques have been developed. The HTS wire, coil configuration, coil former, insulation, and HTS coil winder have been considered in details. The HTS winding is made using multi-unit coils of the same rating and standards, but different processing procedures. Up to 6 HTS units (600m/unit) are required for full operation of the 1 kVA rated HTS FCL device. This flexible HTS winding design will make it possible to build one unit by unit to form the final winding.

A non-metallic cryogenic Dewar using vacuumed double jacketed and reinforced glass fibre plastic container is designed for the HTS bias winding cooling system. The sample container has been tested without vacuum and with low vacuum; its performance is suitable for the operation and testing of HTS coils. The final Dewar is under construction with improvements to better suit low temperatures and higher vacuum. The progress made also includes the following tests, and components designed: The HTS wire has been tested with regard to its compatibility with the HTS winding formation materials and winding processing. The assembled FCL units excluding the HTS system have been built and tested, with their designs confirmed and their windings all demonstrated to be well balanced. The device cabinet (2.6x1.6x1.8m) is being constructed and will accommodate the main part of the HTS FCL device and also its control and operation systems with high current ac and dc switches (up to 1kA). A high current transformer (35kVA), used for a universal ac source, has been designed and is under construction. A universal dc power supply (20kVA) used for the HTS FCL dc bias control, having both current and voltage control functions, has been designed and is under construction. An electronic RC integrated circuit has been built for the device magnetic core flux monitoring and tested with the link to the device flux searching coil and an oscilloscope. Results show it works effectively and allows the FCL B-H curve to be measured and the FCL device monitored. HTS wires for the project were made available by Australian Superconductors Ltd in April this year and the HTS FCL device will be fully assembled in July.

3.3 *Bi-Polar Electrode Materials and Design for Electric Vehicle Batteries*

Funded:	**1998 1999 2000**
Project ID:	C89805127
Chief Investigator:	S.X. Dou, H.K. Liu
Industry Partner:	Australian Battery Technology Ltd Pasminco Ltd Taiyi Battery Ltd. Project
Research Fellow:	S. Zhong
Postgrad. Student:	J.Z. Wang

This project aimed to develop a superior, corrosion-resistant and highly conducting alloy, to design new processing techniques using a lead-coated, glass-fibre net to support positive and negative materials and to construct and evaluate bipolar-electrode battery prototypes to simulate the electric vehicle driving duty cycle. The bipolar lead acid battery is an ideal technology for electric vehicles (EV) batteries because of its potential for high specific power, high specific energy, long cycle life and low cost. In this project a major effort was made on a "quasi-bipolar" lead-acid battery. In the final stage of the project, a quasi-bipolar lead-acid battery was designed and constructed.

Fabricating of woven lead-coated glass fibre grid: Conventional lead acid batteries normally use thick lead grids, which are formed either by casting liquid lead into a mould of the desired configuration or by expanding sheet lead into a mechanically stiff grid. The grid must be made more substantial so that it can act as a latticework to support the active material. Further, the grid itself is relatively fragile, necessitating a construction which is heavier than needed for the grid to perform its electrical function. In this project, a composite wire is fabricated by coating a light-weight, high tensile strength glass fibre with sufficient lead. The resulting composite wire is suitable for use in the grid of the bipolar electrode. A method and apparatus for coating a high tensile strength glass fibre with pure lead has been developed in our laboratory. This composite grid has been used as the prototype battery grid throughout the project. The use of this composite grid had been reported in a previous progress report of this project. A patent application related to the use of this composite grid will be submitted by ISEM with the industry partner.

Construction of the quasi-bipolar lead-acid battery: The quasi-bipolar lead-acid battery has been constructed in the collaborating battery company by a team member from ISEM, UoW. The bipolar electrode element is comprised of a lead-coated glass fibre grid and layers of negative and positive material pastes applied to opposite halves of the grid on opposite sides of the central hot-melt strip. The construction of the prototype quasi-bipolar lead-acid battery includes: (a) a number of bipolar cells arranged side-by-side to form a stack of cells; (b) each bipolar cell being loaded with an electrolyte, a bipolar electrode plate and a pair of separator plates arranged on opposite sides of the electrode plate and sealed the edges of it; and (c) each bipolar electrode plate being composed of a partition sheet and a pair of bipolar electrode elements folded into a hairpin configuration.

Evaluation of the quasi-bipolar lead-acid battery: Advantages of the quasi-bipolar battery design include (1) high voltage of one single battery, (2) maintenance-free operation, (3) operation in any orientation, (4) high specific energy and power, (6) single pressure relief vent, (7) no free acid if structurally damaged and (8) improved life cycle. The specific energy and power of the prototype quasi-bipolar lead-acid battery is capable of achieving ~ 50Wh/kg at C/3 and 270 W/kg at 80% DOD. The technology developed during this project has been licensed by a joint venture company Leadcel Dynamic Energy Ltd through the industry partner, Australian Battery Technology Ltd. Leadcel has invested $2.5milion to build the prototype production line by July this year. It is expected that Leadcel will put high energy batteries onto the market by the end of this year. The research agreement between ISEM and Leadcel has been finalised.

3.4 *Reduction of heat leak of high T_c Superconducting Current Leads*

Funded:	1999	2000	2001
Project ID:	C89922487		
Chief Investigator:	H.K. Liu		
Partner. Investigator:	M. Apperley, R.P. Zhao		
Assoc. Investigator:	B. Zeimetz, T. Chandra		
Postgrad. Student:	Z.M. Zhang		
Industry Partner:	Metal Manufactures Ltd		
Research Fellow:	R. Zeng		

Improved the uniformity of Ag (alloy) sheathed tapes: A new process of high temperature vacuum degas (HTVD) has been developed and employed to eliminate bubbles emerging during Bi-2223/Ag tape processing. Some work to optimize the HTVD process has been investigated. Several long tapes were fabricated using the HTVD process and after the first heat treatment, there were no bubbles in the entire tape. The Ic was measured turn by turn and the variation was found to be about 2A over the whole tape. The homogeneity of long tapes was much improved.

Maximizing the critical current density:

Powder: Some different commercial powders have been used to optimize the process. Effects of some pre-heat treated and HTVD precursor powder on the production process have been studied. So far, the tapes made by the so-called 'high reactivity rods" obtained the highest performance compared with other powders.

Configuration: Thin and narrow, normal and wide different dimension tapes, and 19-, 37-, 61-, 91- filament tapes, normal and thin wall Ag alloy tube tapes have been fabricated to optimize process and tried to increase the filling factor and thereby maximise the Ic, Je and Jc for different applications. Very thin and narrow 19-filament tapes obtained highest Je ($0.11\times2mm^2$, Ic=27.2A, Je~13000A/cm^2), 61-filament high reactivity rods and thin wall Ag-Mg tube wide ($0.23\times4.1mm^2$) tapes obtained highest Ic(~80A).

Deformation: Different green tape deformation procedures and intermediate deformation rates have been studied to improve uniformity, core density and remove cricks in the tapes. It was found that the deformation process needs to be continually adjusted for different precursor powder, different first heat treatment procedure tapes.

Heat treatment : Several heat treatment procedures have been tried to optimize the sintering procedure. First heat treatment (HT1) sintering in air and in low partial pressure O_2 (LpO_2), secondary heat treatment (HT2) sintering in air and LpO_2, and their combined procedures and sintering at different temperature and in different time have been investigated, and the effect on phase transformation and performance of the tapes has been assessed.

Choice of alloyed silver material as sheath material to reduce the thermal conductivity and to enhance the strength for current leads: Au-Ag, Ag-Mg and Ag-Sb alloys have been chosen as sheath materials to reduce thermal conductivity. The initial electrical resistivities of Ag-alloys as-worked at room temperature and liquid N_2 temperature were measured. Compared with pure silver, the resistivity of Ag-Au alloy was about 10 times greater at 77K. The effects of Ag-Au and Ag-Sb alloys on chemical compatibility with the HTS oxide core have been examined. It has been found that Au and Sb alloy elements have only a slight effect on BSCCO superconductor phase formation. A pair of 1000A current leads has been designed. About 100m long Ag-Au tapes have been produced in preparation for constructing current leads.

3.5 *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		

Structural study of Al-substituted nickel hydroxide for Ni-MH battery:

Powder X-ray diffraction is employed to identify the phase structure of A—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 analyzing 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 when the content of Al reaches 15.7 mol%, and the element Al doped in nickel hydroxide substitutes on the position of Ni in the crystalline lattice results in a phase transformation from β to α. A crystallization process occurs both with alkaline ageing treatment, and charge/discharge cycling, which causes growth of crystalline size and a loss of turbostatic disorders.

A method for production of spherical nickel hydroxide for rechargeable nickel-metal hydride and nickel-cadmium batteries has been established:

Spherical agglomerates of nano structured α or β phase of pure or composite nickel hydroxide with general formular $Ni_{1-x-y}M_xMe_y(OH)_2$ (M = transition metal or Al, Me = transition metal) for cathode materials are produced by a method including the following steps: co-precipitation of Ni, or Ni composite hydroxide by adding an aqueous solution of sodium hydroxide to an aqueous mixed solution containing the Ni^{+2} salt and (if applicable) salts of the other metals and using ammonia solution to adjust the PH level; Through washing of the obtained slurry, sodium hydroxide and ammonia remain in the solution. Spray drying process of the slurry leading to formation of spherical agglomerates of pure or composite nickel hydroxide with α or β phase. This method permits production of cathode materials possessing much higher specific surface area and capacity combined with long cycle life than the industrial materials prepared via conventional technology. This method has been filing in the innovation patent application (Innovation patent application number: 2002100676, 02/01/2002).

3.6 *Substrates for large area thin films obtained by pulsed laser deposition*

Funded:	1999	2000	2001
Project ID:	C89922466		
Chief Investigator:	J. Horvat, M. Ionescu		
Partner Investigator:	M. Apperley		
Industry Partner:	Metal Manufactures Ltd., M. Apperley		
Postgrad. Student:	J. McKinnon		

The project continued with the formulation of the major problems encountered during the deposition of Y-123 thin films. The PLD deposition process was divided into three major processes: 1) laser beam-target interaction; 2) atmosphere interaction with the target, plume and the deposited film; and 3) plasma-substrate interaction.

The main striking general feature of the published results for the growth of PLD films is the fact that the growth recipes are system specific. The main implication of this fact is that the reported parameters of the PLD process (laser energy, type of atmosphere, deposition pressure, substrate temperature, etc) are either not fully controlled or they are not the determinant parameters.

It was found that the effect of laser beam-target interaction on the increasing the area of the film is crucial, since operating outside the optimum ablating window results in a rapidly degrading target, the consequence for this being that it is impossible to maintain a steady-state ablation process. The findings were submitted for publication in Physica C.

It was found that the plume-substrate interaction during the PLD process could not be described in a satisfactory way by the existing models, which assume thermodynamic equilibrium. A new model was proposed, termed as 'Selective Retention Model".

Within the framework of this new model, all the known facts related to the growth of PLD films can be adequately accommodated. The key part of the proposed model is the existence of a transient high-pressure layer, which forms above the substrate during its interaction with the plume. Currently we are searching for an appropriate method to monitor this pressure layer.

At the present time the model is being tested in a number of experiments, and some of the results were reported and accepted for publication in Advances in Cryogenics Vol 47.

Apart from Y-123 films, other high-quality films have been grown, such as CeO_2 on single crystal YSZ and on biaxially textured Ni ribbon; $La_{0.8}Ca_{0.2}MnO_3$ on single crystal MgO; $LiNi_{0.8}Co_{0.2}O_2$ on policrystalline stainless steel, on policrystalline Ni, and on biaxially textured Ni.

3.7 *Thermionic cooling for domestic refrigeration*, Project ID: C00001867

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

The ARC support in this project is an APAI. A PhD student, Ben Lough was recruited in July 2000. We have carried out the following research.

(i) We developed several numerical programs to simulate the performance of single and double layer structures. Numerical results for thermal efficiency for various different structures were obtained.
(ii) We designed the first elementary structure for domestic refrigeration.
(iii) We performed electrical measurement to determine I-V characteristics. The asymmetric contact resistance at the top and bottom metal-semiconductor interface were accurately determined.
(iv) We performed thermal and optical measurements to determine the temporal variation of temperature on various electrodes. We found that the device exhibits a net temperature difference between the case where the device is positively biased and the case where the device is negatively biased. This is the first experimental observation on the cooling effect of a multilayer structure.
(v) We performed theoretical analysis on the mechanism of energy transport in multilayer systems. Our results reveal that the interface phonon scattering plays a significant role in the energy transport in the structure.
(vi) We developed simulation codes on the thermal transport to study the optimal operation condition of various structures.
(vii) We discussed and presented the preliminary results at a meeting with Email Ltd. in Orange, NSW, our industry partner.

Results of (i)-(iii) were reported in recent conferences, one paper is to be published [1] and two more papers are being prepared. The results of (iv) and (v) have been published in international refereed journals [2,3]

[1] 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, (in press 2002)
[2] 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).
[3] 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).

3.8 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		

The ARC support in this project is an APAI. A PhD student, Zhijian Dou was recruited at end of 2001. During the summer of 2001/2002, the student has conducted a literature search and equipment calibration. It is planned that Mr Dou will carry out systematic measurements on the temperature distribution using an optical method.

Since the PhD student only started a few months ago the significant outcomes of this project are not expected until 2003.

4. Reports on IREX Project of International Fellowships in 2001

4.1 *Electromagnetic Behaviour of HTS in Various Geometries*, SX Dou, EH Brandt (2000-2001)

Funded: 2000 2001
Project ID: X00001598
Australian Investigator: S.X. Dou
International Investigator: E.H. Brandt

The aim of this project is to improve the electromagnetic measurements by appropriate theories which correctly account for the geometry of the experiment.
Dr Brandt has worked at ISEM for two three-month periods in 2000 and 2001 and collaborated intensively with the ISEM scientists. He contributed to his numerical programs which calculate the magnetic and current-carrying properties of technical superconductors and gave several talks on these topics in the institute's seminar. His collaborators can now use these programs independently and produce useful new results for improving the properties of superconductors. Further scientific publications are in progress and collaboration will be continued by electronic mail between Australia and Germany. During his visits at the ISEM in Wollongong, Dr. Brandt also gave seminars and colloquia at the CSIRO in Lindfied, at the University of NSW in Sydney, and at the Australian National University in Canberra. Various publications in refereed journals have resulted from the visits of Dr. Brandt to the ISEM in Wollongong. In the publication "Theory of Type-II Superconductors with Finite London Penetration Depth" which appeared in July 2001 in Physical Review B, the most important (for application and for theoretical understanding) geometries used in experiments with superconductors are described theoretically, and algorithms are given explicitly to compute the magnetic field and current distributions, magnetic moments and resistivity of the superconductor in each of these geometries: thick and thin strips with applied magnetic field and current, thick and thin disks and short cylinders in axial magnetic field, thin rectangular films and films of arbitrary shape in perpendicular magnetic field. The publication "Geometric Edge Barrier in the Shubnikov Phase of Type-II Superconductors" was written by Dr. Brandt during his stay in Wollongong in 2001.

In collaboration with Dr Brandt, researchers at ISEM have performed numerical study on the levitation forces between a permanent magnet and a superconductor disk with different configuration and geometries. The levitation force is observed to depend non-linearly on the critical current density and on the thickness of the superconductors. The flux creep is described by a current-voltage law, from which it is shown that the levitation force depends on the speed at which the permanent magnet approaches or recedes from the superconductor, which accounts for the observed force creep phenomenon. A 13 page paper has been submitted to Phys. Rev B. A publication together with co-workers at ISEM is in preparation, titled: "Order-Disorder Transition in Bi12212 Single Crystals Doped with Fe and Pb". Further collaboration by electronic mail will continue and will lead to further publications with co-authors. Topics of this continuing collaboration were discussed and the study has begun.

Paper and submitted papers obtained from this IREX program:

K. K. Uprety, J. Horvat, X. L. Wang, H. K. Liu, S. X. Dou and Ernst Helmut Brandt, "Order-Disorder Transition in Bi2212 Single Crystals Doped with Fe and Pb", submitted to *Phys. Rev. B*.

M.J. Qin, G. Li, H.K. Liu, S.X Dou and E.H. Brandt, "Calculation of levitation forces in permanent magnet-superconducting systems", submitted to *Phys. Rev. B*

E.H. Brandt, "Theory of type-II superconductords with finite London penetration depth", *Phys. Rev. B* 64 24505-1-15 (2001)

E.H. Brandt, "Peak effect, vortex-melting line and order-disorder transition in conventional and HTS", *Phys. Rev. B* 64 184514-1-13 (2001)

4.2 *Investigation of Novel Metal Nickel Hydride Electrode for Rechargeable Batteries*

Funded:	2001	2002
Project ID:	X00106668,	
Australian Investigator:	S.X. Dou	
International Investigator:	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 Mg_2Ni 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^{o}C, requiring tedious activation processes. To overcome this problem, we 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 Mg_2Ni by addition of carbon or calcium as an oxygen getter. Several nanocrystalline Mg_2Ni alloys have already been 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, we have prepared several new nanocrystalline alloys and nanocomposites (Ni-Sn, TiC-Sn, TiC-SnO, Ni-Sn-SiO_2, Sn-SiO_2.) 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, we 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*

4.3 *Phase equilibrium diagram of Ag/Bi_2O_3-PbO-SrO-CaO-CuO system*

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

Experimental studies were carried out during the stay of Prof. Peter Majewski, of Max-Planck-Institute for Metals Research, at the Institute of Superconducting and Electronic Materials of the University of Wollongong, May 21 – August 31, 2001.

One of the most exciting developments in recent years has been the discovery of superconducting oxides with critical temperatures (T_c) well above the boiling point of liquid nitrogen (T = 77 K). The discovery of the high-temperature superconducting phases in the Bi-Sr-Ca-Cu-O system ($Bi_{2+x}Sr_{2-y}Ca_{1+y}Cu_2O_{8+d}$, 2212 phase, $T_c \leq 95$ K and $Bi_{2+x}Sr_{2-y}Ca_{2+y}Cu_3O_{10+d}$, 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 provides 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 an 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 $Bi_{2.4}Sr_{1.9}Ca_{2.1}Cu_{3.1}O_{10+x}$ was prepared and pressed into silver crucibles in order to simulate the conditions during tape processing. The samples were annealed at different temperatures and oxygen partial pressures aiming at a definition of the optimum preparation conditions for melt processed 2223 phase. As a result, samples were prepared containing about 60 vol% 2223 phase crystallized from a liquid. The best results were obtained by annealing at temperatures of about 870 °C in air. The obtained results are the basis of additional experiments which are in progress and are performed at the Max-Planck-Institute for Metals Research.

In addition, an extended literature search on phase diagrams was performed which was focused on the new superconductor MgB_2 and related systems, for example Fe-B, Cu-B, and higher systems like the ternary system Mg-Fe-B. The binary systems have been experimentally studied, but thermodynamic optimizations based on CALPHAD do not exist. The ternary systems were not studied, yet. This fact makes it obvious, that a detailed phase diagram studies are necessary in order to obtain knowledge which is essential for processing of superconducting metal sheathed MgB_2 wires. Based on the results of the literature search experiments for a study of the system Mg-Fe-B are outlined which will be performed at the Max-Planck-Institute for Metals Research.

Prof. Majewski will be working at the Institute for Superconducting and Electronic Materials, the University of Wollongong for two and a half months in 2002 to complete this project.

5. Progress Report on Research Infrastructure & Equipment Funding

5.1 *High Resolution Scanning Magnetic Microscope*, SX Dou, R. Lewis, HK Liu, R. Krishnamurthy (Monash), YB Cheng (Monash), R. Ramer (UNSW), J. Mazierska (James Cook University) (2001) Project: R00107847,

The objective of the ARC RIEF is to establish a HRSMM facility with a wide range of capabilities to enable us to obtain local information on magnetic and electrical properties of various materials. Such local information at micrometer level with high sensitivity is essential for studying the current limiting mechanisms in high temperature superconductors.

There are several options to achieve the objective of the proposed facility. A scanning HTS-SQUID microscope is capable of studying magnetic field and current distribution on the samples. However, the sensitivity and stability at low temperatures for the current products is not satisfactory. Thus, a magnetic property measurement system (MPMS) and magneto-optical imaging (MOI) device were purchased and installed by October this year. The performance of MPMS has been well established. Thus, much effort on this project was focussed on the improvement of MOI. MOI is a powerful tool for nondestructive quality control and scientific research through visualization of magnetic fields around any magnetic flux or current carrying sample. It also allows real-time observation of magnetic domain structures and their transformation in static and dynamic magnetic field patterns due to inhomogeneous currents in superconductors. In addition to qualitative magneto-optical analysis it also possible to obtain quantitative maps of field distributions and retrieve values of the underlying currents or magnetization variation.

A low-temperature MOI imaging technique has been set up using a special home-built optical cryostat. Low temperatures in the cryostat are obtained with the help of a cryo-cooler capable of reaching a temperature at the sample under test as low as 19 K. This is sufficient for magneto-optical investigation not only of the high-T_c cuprate samples having their transition temperatures around 100 K, but also of the recently discovered MgB_2 superconducting samples with a transition temperature of about 40 K. The cryostat has been designed to provide transport currents to the sample as high as 60 A, which is important for high transport performance superconducting samples being at low temperatures. Our MOI observations are usually carried out in an external magnetic field in a range from 0 T to about 0.3 T, which is produced by an external solenoid which is designed so that it can be directly immersed into liquid nitrogen. The magnetic field resolution of the system is at least 10^{-5} T which is expected to permit study not only of the magnetic field/current distribution over the superconducting sample, but also the initial flux penetration, screening and geometrical barrier effects observable at low fields of the order of about 10^{-4} T.

The magneto-optical sensitive element, generally rotating the plane of polarization of light in the presence of magnetic fields parallel to the light beam, provides a spatial resolution of the magnetic flux gradient over the sample surface down to 1μm. With this spatial resolution attained, our preliminary results show that we are able to study very fine structure of the magnetic flux "clouds" presumably appearing due to granular structure in the superconducting core of Bi-tapes. The structure exhibits a net of valleys filled with magnetic flux around "clear" areas. The "clear" areas are of about 2 -10μm diameter with ~1μm wide magnetic flux "clouds" around them. The width of the "clouds" might be even smaller making our MOI system unique, but it requires a further more careful investigation. This fine "cloud" structure was able to be captured due to the application of a low-contrast digital camera, which is also potentially capable of providing real-time imaging of a magnetic flux distribution transformation. The live effect produced with the real-time imaging could be described in terms of magnetic "flooding" of a magnetically screened mountain area starting from the edges of the sample towards its interior.

Selected Abstracts

High Temperature Superconductivity Group

Effect of Oxygen Partial Pressure on Processing Conditions And Phase Transformation in Ag/Bi-2223 Tapes **,** Physica C 351, 371-378 (2001)

J.-H. Ahn, H. K. Liu and S. X. Dou

The effect of oxygen partial pressure on processing parameters and phase transformation in Ag/Bi-2223 tapes was investigated using the two-step annealing process at the final thermal cycle of the powder-in-tube process. It was found that the temperature window for processing was widened and the volume fraction of Bi-2223 in the tape increased under low oxygen partial pressure. Using an atmosphere of N_2-7.5% O_2, nearly pure Bi-2223 phase was obtained by a proper control of multi-step annealing temperatures. The maximum J_c and the highest Bi-2223 volume fraction appeared at T1=T2=830^{o}C and T3=785~805^{o}C in N_2-7.5% O_2 atmosphere. The samples annealed in N_2-7.5% O_2 retained well their J_c values over a wide temperature range of 785~805^{o}C with only 10% deviation from the highest value. In contrast, for the same level J_c retention the temperature window would be narrowed down to a half of this range. These results demonstrate that the heat treatments in N_2-7.5% O_2 atmosphere are advantageous for processing of Bi-2223/Ag tapes in large scale as there would be much less demand on temperature control.

Optimized $NdBa_2Cu_3O_y$ thin films deposited by eclipsed pulsed laser ablation, Physica C 356(2001) 205-211

C. Cai, M. Tachiki, T. Fujii, T. Kobayashi , H.K. Liu and S.X. Dou

$NdBa_2Cu_3O_y$ (Nd123) thin films are deposited on (100) MgO, (100) Y-stablized ZrO (YSZ) and (100)$SrTiO_3$ (STO) at the low temperature of 650 by pulsed laser ablation with a shadow mask(eclipsed PLD). X-ray diffraction and reflection high-energy electron diffraction patterns show that all thin films are oriented in (00l) direction. Compared with the conventional PLD samples, the eclipsed PLD samples exhibit a narrower superconducting transition width (ΔT_c). The suppression of ΔT_c is believed to result from the elimination of droplets and the stoichimetric deviation of Nd specie. The film on STO shows better superconducting properties than those on YSZ and MgO. Its onset T_c, ΔT_c and J_c reaches 93.5K, 3.5K and 6x10^{6}A/cm^2, respectively. A Nd123/MgO thin film step-edge junction is prepared as well. Typical RSJ-like (Josephson) current-voltage curve is observed.

Crystal Growth Patterns in the MgO Seeded $Y_{1.8}Ba_{2.4}Cu_{3.4}O_y$/Ag Melt-texturing Process, Physica C 357-360 (2001) 734-737

C. Cai, H. Mori, H. Fujimoto, H. Liu, and S.X. Dou

Present work shows that the MgO seeded growth pattern in the isothermal solidification of $Y_{1.8}Ba_{2.4}Cu_{3.4}O_y$/Ag usually consists of two basic types of crystal growth facets. One is high-angle rotation about the (100) plane of MgO single crystal, while the other is parallel to the plane. The preferred growth facet with 45^o rotation is enhanced to be only one type as the undercooling decreases. The domain structure is checked by transmission electron microscopy and selected area electron diffraction. Lattice matching relationship between MgO and Y123 in the melt-texturing process agrees with what is seen in various vapor phase epitaxial growths as well as the predictions of simplified near coincidence site lattice theory.

Comparative Studies on Sandwich Rolling and Flat Rolling in Processing Ag/Bi2223 tapes, IEEE Appl. Supercond. 11, 3752-3755 (2001)

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

It has been well established that microcracks generated through intermediate deformation put a severe limitation to the critical current of Ag/Bi-2223 tapes. The normal rolling is commonly used for the intermediate mechanical deformation in the powder-in-tube process to make Ag-clad Bi-based superconducting tapes. Recently, we have systematically studied the reduction rate dependence of critical current densities J_c of Ag/Bi-2223 tapes using three methods including the normal rolling, pressing and "sandwich" rolling. Experimental results show that J_c dependence on the reduction rate for the three processes follows the same law, that is, J_c is proportional to physical density in each case. The relationship between intermediate mechanical deformation processing and the final current density of the tape can be precisely expressed by a Gauss function. There is an optimal reduction rate in each case, which gives the highest physical density and the highest J_c. When the reduction rate increases, J_c increases first, reaches a maximum and then reduces. Correspondingly, the density-reduction rate follows the trend. However, the maximum J_c of the Ag/Bi-2223 tapes made using sandwich rolling is 40% higher than using normal rolling even though the tapes in both cases have the same density of the oxide core. This indicates that sandwich rolling reduces the cracks along the transverse direction in the tape compared with normal rolling. Magneto-optical imaging (MOI) shows that the normally rolled tapes have much more microcracks in the transverse direction than the sandwich-rolled tapes. It is evident that J_c of the tape is strongly dependent on oxide core density and deformation procedure.

Effect of various mechanical deformation techniques on J_c - H dependence for Ag/Bi-2223 tapes,Physica C **354**, 349-352 (2001)

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

Ag/Bi-2223 tapes were fabricated using the Powder-In-Tube method. Thermo-mechanical processing was carried out using two thermo-cycle heat treatment with an intermediate deformation including sandwich rolling (SR), pressing (P) and normal rolling (NR). Experimental results showed that critical current densities J_c of Ag/Bi-2223 tapes, processed using SR, P and NR, reached their maximum at a reduction rate of 22%, 25% and 23%, respectively. The self-field-J_c showed a linear relationship with the relative density for SR-, P- and NR-tapes, but the slopes of the linear dependency were different for the three deformations. SR tape had the largest slope, P the second and NR the third, respectively. Magnetic field dependence of J_c was measured at 77 K for SR-, P- and NR-tapes with magnetic field applied parallel to the board face and edge tapes i.e. the fields were applied parallel to the a-b face and c-axis of average Bi-2223 grains, B//ab and B//c, respectively. Pinning force density F of SR-, P- and NR-tapes were calculated for B//ab and B//c, respectively. Maximum values of F were different for SR-, P- and NR-tapes. The irreversible magnetic field Birr of SR-, P- and NR-tapes showed similar trend. As compared to pressing and normal rolling, above experimental evidence supported that the sandwich rolling was the best intermediate deformation method to improve the J_c of Ag/Bi-2223 tapes.

The Upper Critical Field H_{c2} of Ag/Bi-2223 Tapes, J. Supercond. 14, 463-466 (2001)

W. M. Chen, F. Wang, S. S. Jiang, H. K. Liu and S. X. Dou

The upper critical field H_{c2}, based on Ginzburg-Landau theory, can be calculated from the relation of the magnetization M vs magnetic field H if at medial magnetic fields M is linear with ln$H$. The J dependence of the magnetic field, $J(H)$, of the Ag/Bi-2223 tape were measured at different temperatures, T. Based on Bean model, $J(H)$ can be translated into $M(H)$. $M(H)$ were found to have a linear relationship with $\ln\mu_o H$. In this case, the values of $H_{c2}(T)$ may in principle be determined. However, the tilting of crystal planes in the tape is not equal for different grains, and the determined H_{c2} are affected from the unequal tilting. To avoid this

influence, the quantities of H projecting onto c axis are taken as the actual applied fields. Furthermore, the quantities of tilting angle θ included in the projected field may be counteracted, if the external fields are applied to the tape along to the both of its board and narrow surfaces when measuring J. Thus, the upper critical fields H_{c2} on c axis for Ag/Bi-2223 tape are obtained. The slope of the curve on average $d[\mu_o H_{c2}(T)]/dT \approx -8T/K$ is as large as that of Bi-2212.

Intrinsic Deformation Behaviour in Pressed Bi-Sr-Ca-Cu-O Tapes, Superconductor Science and Technology 14 (10), 862 (2001).

H.T. Cooper, W. Gao, S. Li, H.K. Liu and S.X. Dou;

It was reported that the critical current density in superconductor tapes can be improved by using cryogenic processing. In present work, the grain alignment characteristics of Bi-Sr-Ca-Cu-O tapes processed via cryogenic and room temperature pressing were investigated. The results shows that $(Bi_{1.84}Pb_{0.34})Sr_{1.91}Ca_{2.04}Cu_{3.06}O_x$ tapes prepared under these conditions have similar phase transformations and grain growth characteristics. However, the grain alignment of the tapes were found to be markedly different, with cryogenic pressing better grain alignment at lower deformation. It is proposed that the alignment occurs due to two factors: 1) The point at which fracture of the grains occurs and 2) Rotation or movement of these grains into the preferred alignment. The differences between the two processes is due to the way in which these two factors combine. The cryogenically pressed tapes showed a step-like increase in grain alignment at approximately 30% deformation, while the increase for the room temperature pressed tapes was gradual.

Phase Transformation Characteristics of BSCCO Tapes Processed via Cryogenic and Room Temperature Pressing, Superconductor Science and Technology 14 (8), 533 (2001).

H. Cooper, S. Li, W. Gao, H. K. Liu and S. X. Dou

The current investigation studies the phase transformation process of Bi-Sr-Ca-Cu-O (BSCCO) tapes processed by cryogenic, 77K, and room temperature pressing. The work specifically examined the effect of deformation on the phase content and transformation kinetics of the BSCCO tapes. The results showed that cryogenic pressing produced tapes with higher Bi2223 phase content at lower deformation ratios than room temperature pressed tapes. However the phase transformation profiles for both tapes were similar. A minimum phase content was observed in the profiles that was characteristic to each process. The minimum occurred between 30-40% deformation for the cryogenically pressed tapes and between 50-60% for the room temperature pressed tapes. The peculiar profiles were suggested to be the result of two competing mechanisms that reduced the free energy of the systems. It was suggested that these two mechanisms were either Bi2212 re-crystallisation or Bi2223 phase formation. The differences observed between the two processes were attributed to the amount and way in which the deformation energy was transferred to the tape.

Flux Jumping and a Bulk-to-Granular Transition in the Magnetization of a Compacted and Sintered MgB_2 Superconductor, Phsyica C, 361, 79-83 (2001)

S.X. Dou, X.L. Wang, J. Horvat, D. Milliken, A.H. Li, K. Konstantinov, E.W. Collings, M. D. Sumption* and H.K. Liu

In this paper, we report the results of field (H) and temperature (T) dependent magnetization (M) measurements of a pellet of uniform, large-grain sintered MgB_2. It was found that iron is compatible with MgB_2 and can be used as sheath material for fabrication of Fe-clad MgB_2 wires. We show that at low temperatures the size of the pellet and its critical current density, $J_c(H)$ -- i.e. its M(H) -- ensure low field flux jumping, which of course ceases when M(H) drops below a critical value. With further increase of H and T the individual grains decouple and the M(H) loops drop to lower lying branches, unresolved in the

usual full M(H) representation. After taking into account the sample size and grain size, respectively, the bulk sample and the grains were deduced to exhibit the same magnetically determined J_c' s (e.g. 10^5A/cm^2, 20 K, 0T) and hence that for each temperature of measurement J_c(H) decreased monotonically with H over the entire field range, except for a gap within the grain-decoupling zone.

Effect of the sinter-forging deformation rate on properties of Bi-2223 current leads, IEEE Trans. On App. Supercon. 11, 1, 2551-2554 (2001).

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

The influence of the sinter-forging rate on critical current density behaviour (J_c) in an external field and on contact resistance R_c for Bi-2223 current leads has been investigated. The current leads were fabricated by a combination of Cold Isostatic Pressing (CIP) and sinter-forging methods with the thickness reduction rate ranging from 0% to 90%. The two silver contact ends of each sample were also prepared during the sinter-forging. The results revealed that J_c was strongly affected by the deformation rate of sinter-forging and reached a maximum of 725 A/cm^2 at a deformation rate of 80%. From the measurements of external magnetic field dependence on J_c, it was determined that sinter-forging could improve J_c behaviour in external fields, particularly in the regime below 50×10^{-3} Tesla (i.e., 50 mT). Measurements of contact resistance R_c were conducted for different transport currents at 77 K. Results showed that the contact resistance for the samples with higher deformation rates became less dependence on the transport current over a range of 0.5 A to 50 A.

Phonon modes of A(Co½Mn½) O-3 (A = La, Nd, Dy, Ho, Yb), Journal of Solid State Chemistry. 160(2):350-352, (2001)

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

Phonon energies in cobaltite/manganites A($Co\,\frac{1}{2}\,Mn\,\frac{1}{2}$)$O_3$, where A is lanthanide, have been determined by far-infrared spectroscopy. The phonon energies systematically shift and split and new modes appear as the mass of the lanthanide is increased through the series A = La, Nd, Dy, Ho, Yb. This behavior of the phonon modes correlates with the magnetic properties of this series of compounds, in particular with the appearance of metamagnetism for the compounds with smaller ions on the A site.

Synthesis and magnetic properties of perovskite $La_{1-x}Ca_xMn_{0.9}Li_{0.1}O_3$, Journal of Alloys & Compounds. 325(1-2):281-284 (2001)

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

$La_{1-x}Ca_xMn_{0.9}Li_{0.1}O_3$, was synthesised by solid-state reaction for different doping levels of Ca, from x=0.1-0.5. The crystal structures of the compounds were studied using X-ray diffraction. We found that the compound was of orthorhombic structure for all Ca doping levels. The lattice parameter decreased gradually with increasing Ca concentration. Infrared absorption spectroscopy revealed a shift in the (Mn, Li)O_{-3} phonon modes relative to MnO_3 compounds. The magnetic properties of the compound were investigated by measuring the AC susceptibility. It was found that the ferromagnetic transition temperature T-c depended on the doping level nonmonotonically. For x <0.3, T-c increased with x while for x >0.3, T-c decreased with x. The magnitude of magnetic susceptibility, chi, varied with Ca concentration in a nonmonotonic manner. The dependence of T-c and chi on Ca concentration is briefly discussed in terms of a phase transition from ferromagnetic order to canted ferromagnetic order.

Improved uniformity of microsctructure and electrical properties of Bi-2223/Ag superconducting tapes, Physica C **355** 163-171 (2001)

Y.C. Guo, W.M. Chen, H.K. Liu, S.X. Dou, A. V. Lukashenko

A special mechanical deformation technique, 'sandwich' rolling (SR), together with the conventional rolling technique, normal rolling (NR) was used to intermediately deform Bi-2223/Ag superconducting tapes. The tapes processed by these two techniques were compared in terms of phase composition, microstructure, critical temperature (T_c) and critical current density (J_c). It was found that while there was no difference in phase composition between the two types of tapes, density, degree of grain alignment and J_c were considerably higher in the SR tapes than in the NR tapes. In particular, the uniformity of microstructure T_c and J_c between the filaments across the width of the tapes were significantly improved by the SR compared to the NR technique. The results show that in terms of mechanical effects on Bi-2223/Ag tapes SR is more like uniaxial pressing, rather than conventional rolling.

Improvement of critical current in MgB_2/Fe superconducting wires by a ferromagnetic sheath**,** Appl. Phys.Lett. **80**, 829-831(2002)

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

Transport critical current (I_c) was measured for Fe-sheathed MgB_2 round wires. A critical current density of 5.3 x 10^4 A/cm^2 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 MgB_2/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.

Paramagnetic Meissner effect in MgB_2 superconductor**,** Submitted to Phys. Rev. B

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

Paramagnetic Meissner effect (PME) was observed for the first time in MgB_2 pellets and superconducting cores of the iron sheathed MgB_2 wires. As opposed to the Meissner effect, the PME consisted of the paramagnetic dc susceptibility in a limited range of the fields. PME was observed in the field-cooled, but also in the zero-field-cooled susceptibility. The later distinguishes it from the PME in the conventional and high-temperature superconductors. PME in MgB_2 is in a metastable state connected with the vortex pinning. It cannot be described by the models commonly used for PME in the conventional and high-temperature superconductors. Instead, it is in good agreement with a model based on self-consistent solutions of Ginzburg-Landau equations for a finite size superconductor.

The crystal structure and magnetic properties of 1-dimensional dihalide-bridged polymers dichlorobis(thiazole)cobalt(II) and dibromobis(thiazole)-cobalt (II), Journal of Physics and Chemistry of Solids **63**, 657-663 (2002)

M. James and J. Horvat

The isostructural polymeric compounds ($Co(thiazole)_2X_2$(X=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, β = 94.78(1)°, *v* = 967.1(3) $Å^3$, *z* = 4; (**2**) *C2/c*, *a* = 18.079(3) Å, *b* = 3.8138(8) Å, IcI = 15.022(4) Å, β = 92.71(1)°, *v* = 1034.6(4) $Å^3$, *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.

The Effect of Mechanical Deformation on the Phase transformation of BSCCO Superconductors, Physica C, 356 (3), 197 (2001).

S. Li, W. Gao, H. Cooper, H.K Liu and S.X. Dou

Mechanical deformation has been widely used to produce textured microstructures to improve the critical current density of Bi2223 superconducting tapes. However, the effect of mechanical deformation on the phase transformation of the BSCCO system has not been well understood. The present research studies the relations between mechanical deformation and the phase transformation kinetics. The results showed that the Bi2223 phase abundance firstly decreased when the mechanical deformation was increased from 20% to 60%, and then increased as the deformation was increased above 60%. The 60% thickness reduction, therefore, resulted in the lowest Bi2223 phase abundance. The effects of mechanical deformation on the distribution of the Bi2223 phase across the thickness of the tape and the grain size of Bi2223 and Bi2212 phases were also studied. The experimental results have been explained by considering the different dominant energies associated with the different mechanical deformation regimes.

Fast formation and superconductivity of MgB2 thick films grown on stainless steel substrate, Physica C. 361(2):73-78, 2001

A.H. Li, X.L. Wang, M. Ionescu, S. Soltanian, J. Horvat, T. Silver, H.K. Liu and S.X. Dou

The fabrication, characterisation, and superconductivity of MgB2 thick films grown on stainless steel substrate were studied. X-ray diffraction (XRD), scanning electron microscopy, and magnetic measurements were carried out. It was found that the MgB2 thick films can be fast formed by heating samples to 660 degreesC then immediately cooling down to room temperature. XRD shows above 90% MgB2 phase and less than 10% MgO. However, the samples sintered at 800 degreesC for 4 h contain both MgB4 and MgO impurities in addition to MgB2. The fast formed MgB2 films appear to have a good grain connectivity that gives a J(c) of 8 x 10 (4) A/cm (2) at 5 K and 1 T and maintained this value at 20 K in zero field.

Magneto-Optical Images of Ag/Bi-2223 Tapes Processed by Flat Rolling, "Sandwich" Rolling and Pressing, IEEE Trans. Appl. Supercon. **11**, 1, 3764-3767 (2001)

Hua K. Liu, Anatolii Polyanskii, Wu M. Chen, Yuan C. Guo, Shi X. Dou, Miles Apperley

Magneto-optical imaging (MOI) has been used for study Ag/Bi-2223 tapes processed using flat rolling, "sandwich" rolling, and pressing methods for the intermediate mechanical deformation in powder-in-tube process. The results show that not only the density of the microcracks but also their distribution affect J_c. Rolled tapes have a higher density of microcracks than pressed tapes. Although the flat rolled tape and "sandwich" rolled tape have the same level density of microcracks at the same reduction, the cracks in the former are more in the transverse direction than in the latter. In all three cases, J_c reaches a maximum value at an optimal reduction rate.

Effects of Uranium Doping and Thermal Neutron Irradiation on Ag/Bi-2223 Tapes, IEEE Transactions on Applied Superconductivity, vol. 11, no. 1, pp3896-3899, March 2001.

Damian Marinaro, Shi X. Dou, Josip Horvat, John Boldeman and Roy Weinstein

Ag/Bi-2223 tapes doped with small quantities of UO_4 powder were prepared by the powder-in-tube process and irradiated in a thermal neutron environment. Substantial improvements in J_c - H performance and anisotropy have been previously reported. However, the radioactivity of the Ag sheath is a limiting factor for commercial and industrial applications of this technique.

Here we report the performance of the technique using various doping levels (from 0.15 to 2 wt% UO_4) and thermal neutron fluences, in order to further reduce the Ag radioactivity. Optimum fluence levels for each doping percentage are identified and an optimum combination in terms of J_c - H performance is discussed. At a doping level of 2% UO_4, a normalised J_c enhancement of 250 times is observed for an 0.8T field aligned along the c-axis, and 25 times at 3T along the ab-plane at 77K, compared to pre-irradiation values. At 0.6%, these figures are 500 and 10 times, respectively.

The effects of the uranium doping and thermal neutron irradiation on the flux pinning strengths are also directly probed using dynamic relaxation techniques. The results show an increase in the effective pinning potential after doping and irradiation.

Scaling of the Magnetic Response and Field Dependence for the Characteristic Pinning Energy in (Y,Nd)$Ba_2Cu_3O_{7-\delta}$ Superconductor Science and Technology **14**, 311-314 (2001)

A.S. Mahmoud, G.J. Russell, M.R. Koblischka, N. Chikumoto, M. Murakami, J. Horvat and S.X. Dou

Magnetic hysteresis loops for the superconductor (Y,Nd)$Ba_2Cu_3O+7_{-\delta}$) have been measured using a SQUID and a vibrating sample magnetometer. The field dependence of the current density and volume pinning force showed well developed maxima and their tempterature-dependent characteristics were used to construct different scaling types. The measurement of magnetic hysteresis loops at different sweep rates enabled the field dependence of the characteristic pinning energy to be determined. In all cases a remarkable consistency with the Perkins et al (1996 Phys Rev. B **54** 12 551) model was found, while the field dependence of the characteristic pinning energy appeared to be inconsistent with the collective pinning theory predication.

Phase Formation and Thermal Treatment Optimisation in Uranium Compound Doped $(Bi,Pb)_2Sr_2Ca_2Cu_3O_x$/Silver Superconducting Tapes, Physica C **354**, 183-188 (2001)

D Milliken, J.H. Ahn and S X Dou

A combination of uranium doping with thermal neutron irradiation has been well demonstrated to be one of the most effective means to introduce pinning centres to Ag/Bi-2223 tapes. A substantial improvement in flux pinning and reduction of anisotropy in uranium-doped Bi-2223/Ag tapes was achieved due to thermal neutron irradiation. However, the radioactivity of silver sheath is too high for practical application of this technique. In the current study, a number of U-containing compounds, $UO_{3.5}$, UCa_2O_5 and $UCa_{1.5}Sr_{1.5}O_6$ have been used as dopants. The compatibility and interaction between U-compound and Bi-2223 matrix was systematically studied at various thermal processing conditions. $UCa_{1.5}Sr_{1.5}O_6$ shows a remarkable compatibility with Bi-2223 phase, with critical current density reduced to about 10% at doping level of 3.0wt%, compared with the 90% reduction in critical current density at the same doping level for pure U-oxide doping. XRD results show that $UCa_{1.5}Sr_{1.5}O_6$ promoted the Bi-2223 formation while $UO_{3.5}$ caused the degradation of Bi-2223 phase up to 50%. The U-compound doping also widens the processing window to 15^{o}C.

Vortex matter in superconductors, Low Temperature Physics, Volume 27**,** Number 9-10**,** September-October 2001, pages 732-746 [Fiz. Niz. Temp. 27, 991-1011 (September-October 2001).

V. M. Pan, A. V. Pan

The behavior of the vortex ensemble in Shubnikov phase in biaxially oriented films of the high-temperature superconductor $YBa_2Cu_3O_{7-\delta}$ (YBCO) in an applied magnetic field is investigated for different orientations of the field. The techniques used are the recording of the current-voltage characteristics in the transport current and of resonance curves and damping of a mechanical oscillator during the passage of a transport current. It is shown that the behavior of the vortex ensemble in YBCO films, unlike the case of single crystals, is determined by the interaction of the vortices with linear defects – edge dislocations, which are formed during the pseudomorphic epitaxial growth and are the dominant type of defect of the crystal lattice, with a density reaching 10^{15} lines/m^2. The effective pinning of the vortices and the high critical current density ($J_c \geq 3\times10^{10}$ A/m^2 at 77 K) in YBCO films are due precisely to the high density of linear defects. New phase states of the vortex matter in YBCO films are found and investigated in quasistatics and dynamics; they are due to the interaction of the vortices with crystal defects, to the onset of various types of disordering of the vortex lattice, and to the complex depinning process. An H-T phase diagram of the vortex matter for YBCO films is proposed.

Evidence for vortex pinning induced by fluctuations in the transition temperature of MgB2 superconductors, Physical Review B, **65**, 132508 (2002)

M. J. Qin, X. L. Wang, H. K. Liu, and 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} 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.

Dependence of the flux-creep activation energy on current density and magnetic field for the MgB2 superconductor, Physica C **356** 303-310 (2001)

M. J. Qin, X. L. Wang, S. Soltanian, A. H. Li, H. K. Liu, and S. X. Dou

Systematic ac susceptibility measurements have been performed on an MgB_2 bulk sample. We demonstrate that the flux creep activation energy is a nonlinear function of the current density $U(j) \propto j^{-0.2}$, indicating a non-logarithmic relaxation of the current density in this material. The dependence of the activation energy on the magnetic field is determined to be a power law $U(B) \propto B^{-1.33}$, showing a steep decline in the activation energy with the magnetic field, which accounts for the steep drop in the critical current density with magnetic field that is observed in MgB_2. The irreversibility field is also found to be rather low; therefore, the pinning properties of this material will need to be enhanced for practical applications.

Growth orientation and surface morphology of CeO2 films deposited by PLD using different deposition atmospheres, Physica C 356 (2001) 303-310.

D.Q. Shi, M. Ionescu, J. Mckinnon, S.X.Dou

We have deposited CeO2 films on yttrium stabilised zirconia YSZ <100> single crystal substrates by pulse lase deposition (PLD) using O2 and Ar+10%H2 atmosphere. For oxygen atmosphere, a pure c-axis orientation of CeO2 film was obtained within the substrate temperature range of 760~820°C. For Ar+10%H2 atmosphere, the same pure c-axis orientation of the CeO2 film was obtained for a much wider substrate temperature range of 350°C -775°C. There are significant differences in the surface morphology of CeO2 films deposited in O2 and Ar+10%H2 atmospheres under the same conditions. For CeO2 films deposited in O2, the size and number of outgrowth formations is large, whilst for the CeO2 films deposited in Ar+10%H2, the surface is smooth and there are very few large outgrowths. For CeO2 film deposited using an O2 atmosphere there is a critical thickness of the film of approximately 200nm, above which the surface roughness rapidly increasing. The relationship between epitaxial temperature and surface roughness of CeO2 films was analyzed.

High transport critical current density above 30 K in pure Fe-clad MgB_2 tape, Physica C **361**, 84-90 (2001)

S. Soltanian, X.L. Wang, I. Kusevic, E. Babic, A.H. Li, M.J. Qin, J. Horvat, H. K. Liu, E.W. Collings, E. Lee, M.D. Sumption, and S.X. Dou

Fe-clad MgB2 long tapes have been fabricated using a powder-in-tube technique. An Mg + 2B mixture was used as the central conductor core and reacted in–situ to form MgB2. The tapes were sintered in pure Ar at 800 ^{o}C for 1 h at ambient pressure. SEM shows a highly dense core with a large grain size of 100 μm. The Fe clad tape shows a sharp transition with transition width of ΔTc of 0.2 K and a Tc0 of 37.5 K. We have achieved the highest transport critical current reported so far at 1.7×10^4 A/cm^2 for both 29.5 K in 1 Tesla and 33 K in zero applied field . Resistivity temperature dependence and transport critical current were also measured in magnetic fields applied perpendicular and parallel to the tape plane. Not only is the use of an Fe sheath necessary for the successful processing of in-situ-reacted powder-in-tube MgB2, it confers on the finished wire the additional benefit of magnetic screening.

Effects of Cr doping on the structure, charge-ordering, transport and spin ordering state in $Nd_{0.5}Sr_{0.5}Mn_{1-x}Cr_xO_3$, Physica C **364-365**, 343-346 (2001)

S. Soltanian, X.L. Wang*,H.K. Liu, J. Horvat, T. Silver, and S.X. Dou.

The effects of cation substitution in the manganese site of charge-ordered $Nd_{0.5}Sr_{0.5}MnO_3$ have been investigated to elucidate how the properties of this material change with chromium doping. $Nd_{0.5}Sr_{0.5}Mn_{1-x}Cr_xO_3$ (x = 0, 0.05, 0.1, 0.15, 0.2, 0.25) compounds have been studied by X-ray diffraction and transport and magnetic measurements. All samples were determined to be single phase and crystallized in an orthorhombic structure. Magnetic measurements showed that chromium doping decreases the charge-ordering temperature T_{co} as x values are increased from 0 up to 0.05. The charge-ordering is completely destroyed for all the higher Cr doping levels (x > 0.05), and the material changes from an antiferromagnetic insulator to the ferromagnetic metallic state for 0.05 <x < 0.2. The resistivity decreases as the result of a metal-insulator transition for x < 0.2, but the resistivity increases, and the material becomes an insulator if x > 0.2. At the same time, the magnetization increases with increasing Cr content, reaches a maximum for x=0.15 and then decreases for x>0.15. It is proposed that Cr destroys the charge ordering and facilitates double exchange between Mn^{3+}-O-Mn^{4+}. It is thus responsible for the ferromagnetic metallic state seen at low Cr doping levels, while an antiferromagnetic interaction between Mn^{4+}-O-Cr^{3+} or Cr^{3+}-O-Cr^{3+} is responsible for the insulator state at high Cr doping levels.

Characteristics of Microtexture and Mesotexture in $(Bi,Pb)_2Sr_2Ca_2Cu_3O_{10}$ Superconducting Tapes, Superconductor Science and Technology 14 (7), 471 (2001).

T.T. Tan, S. Li, H. Cooper, W. Gao, H.K. Liu and S.X. Dou

Grain boundary misorientation is known to limit the critical current density of bulk high temperature superconductors. However, the effect of mechanical deformation on the texture evolution during PIT processing remains unclear, especially on the microstructural level. In present work, the micro- and meso-texture characteristics of PIT processed $(Bi,Pb)_2Sr_2Ca_2Cu_3O_{10}$ (Bi2223) superconductor tapes was investigated. The results in microtexture show that a/b axes texture does exist in PIT processed tapes. From the meso-texture studies, it was found that a majority of the grain boundaries were formed by grains with non-parallel c-axis. These grain boundaries generally have low mismatch angles of up to ~10°. High-angle misorientation boundaries ranging up to 45° are generally c-axis twist boundaries. Further, about 40% of the grain boundaries could be coupled strongly.

Transverse Micro- and Mesotexture Distribution Characteristics on the Core Surface of $(Bi,Pb)_2Sr_2Ca_2Cu_3O_{10}$/Ag Superconductor Tape, Superconductor Science and Technology 15 (2), 241

T. T. Tan, S. Li, W. Gao, H. K. Liu and S. X. Dou

Powder-in-tube (PIT) processing of BiSrCaCuO superconductor is widely used to introduce textured microstructure to high temperature superconductor tapes, thus effectively minimizing the weak-link effects caused by grain boundary misorientations. Although it was reported that PIT tapes have parabolic critical current density (J_c) distribution across the tape width, the role played by texture in this is not clearly understood. In this work, both the micro- and meso-texture of PIT processed $(Bi,Pb)_2Sr_2Ca_2Cu_3O_{10}$ (Bi2223) superconductor tapes were analyzed in the transverse direction of Bi2223 tapes. Micro-texture and meso-texture of PIT processed Bi2223 tapes were characterised using angle-axis pairs and Rodrigues-Frank vectors. The results of micro-texture evaluation indicates that a/b axes texture did exist in PIT processed tapes while the meso-texture RF plot exhibits that majority of the grain boundaries were formed by grains with non-parallel c-axis. These grain boundaries generally had low mismatch angles of up to ~10°. High-angle misorientation boundaries ranging up to 45° were generally associated with c-axis twist boundaries. The dominating misorientation angle for both sample sides and center was found to be 4^o. It is believed that

the micro- and mesotexture distribution characteristics has influence over the J_c distribution in the transverse direction of Bi2223 tapes.

Crystallographic Orientation Mapping with Electron Backscattered Diffraction Technique in $(Bi,Pb)_2Sr_2Ca_2Cu_3O_{10+x}$ Superconductor Tapes, Superconductor Science and Technology 14 (2), 78 (2001).

T. T. Tan, S. Li, J. T. Oh, W. Gao, H. K. Liu and S. X. Dou

It is believed that the grain boundaries act as weak-links in limiting the critical current density (Jc) of bulk high-T_c superconductors. The weak-link problem can be greatly reduced by elimination or minimization of the large-angle grain boundaries. It has been reported that the distribution of the Jc in $(Bi,Pb)_2Sr_2Ca_2Cu_3O_{10+x}$ (Bi2223) superconductor tapes presents a parabolic relationship in the transverse cross-section of the tapes, with the lowest currents occurring at the center of the tapes. It was proposed that the Jc distribution is strongly dependent on the local crystallographic orientation distribution of the Bi2223 oxides. However, the local three dimensional crystallographic orientation distribution of Bi2223 crystals in $(Bi,Pb)_2Sr_2Ca_2Cu_3O_{10+x}$ superconductor tapes has not been experimentally determined yet. In this work, Electron Backscattered Diffraction technique was employed to map the crystallographic orientation distribution, determine the misorientation of grain boundaries and also map the misorientation distribution in Bi2223 superconductor tapes. Through crystallographic orientation mapping, the relationship of the crystallographic orientation distribution, the boundary misorientation distribution and the fabrication parameters may be understood. This can be used to optimize the fabrication processes thus increasing the critical current density in Bi2223 superconductor tapes.

Improved in-field behaviour of Uranium Doped BiSCCO Tapes by Enhanced Flux Pinning, IEEE Trans. Appl. Supercond. **11**, **1**, 3904-3907 (2001)

S. Tönies, H.W. Weber, Y.C. Guo, S.X. Dou, R. Sawh and R. Weinstien

Uranium doped BiScCCO 2223 tapes were irradiated by thermal neutrons. The resulting fission-induced defects improve flux pinning and shift the irreversibility line to higher fields. Significant enhancements of the transport critical current density as well as a reduction of the J_c anisotropy are found for the irradiated samples. Furthermore, inter- and intragranular critical current densities were determined from the remanent magnetic moments by SQUID magnetometry.

On the Current Transport Limitations in Bi-based high temperature superconducting Tapes, Applied Physics Letters, **78, 24**, 3851-3853 (2001).

S. Tönies, H.W. Weber, Y.C. Guo, S.X. Dou, R. Sawh and R. Weinstien

The transport critical current densities, J_c of superconducting $(Bi,Pb)_2Sr_2Ca_2Cu_3O_x$/Ag tapes were measured before and after employing a special radiation technique, which leaves the grain boundary properties largely unaffected. We identify two regions separated by a temperature dependent crossover field $H_{gp\text{-}p}$. In the low field region, J_c is limited by the transport currents across the grain boundaries, which remain unchanged after irradiation. Above $H_{gb\text{-}p}$, J_c is limited by flux pinning. In this field region, the artificial defects optimise flux pinning and enhance J_c.

Enhancement of vortex pinning by Josephson coupling of two-dimensional pancake vortices in heavy lead-doped $Bi_{2-x}Pb_xSr_2CaCu_2O_y$ Superconductor Science and Technology; Volume 14, Pages 479-485, (2001)

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

Magnetic hysteresis loops and magnetic relaxation have been measured for pure and heavily lead doped Bi2212 single crystals. From the hysteresis loop measurements, the normalised critical current density J_c/J_{c0} has been calculated, and from the relaxation measurements, the activation energy, current-voltage curves and normalised relaxation rate have been obtained. The field and temperature dependence of J_c/J_{c0} for Pb doped crystal was much weaker than for the pure Bi2212 crystals. A large upward shift in the crossover temperature T_{CR}, a temperature separating two different pinning regimes, has been observed for the first time with heavy lead doping. This was interpreted by improved inter-layer Josephson coupling of 2D vortices, as a result of Pb-doping. Heavily Pb doped crystal had T_{CR} = 35 K for the field that was within the secondary peak in its magnetic hysteresis loop. For pure Bi2212, T_{CR} = 19 K.

Superconductivity and flux pinning in Y and heavily Pb codoped Bi-2212 single crystals, Journal of Applied Physics. 89(11 Part 2):7669-7671, (2001)

X.L. Wang, H.K. Liu, S.X. Dou, J. Milliken, G. Heine, W. Lang, H.M. Luo, S.Y. Ding

Studies of superconductivity and flux pinning were carried out on (Bi1.64Pb0.36)Sr2Ca1 - xYxCu2O8 + y (x = 0, 0.05, 0.11, 0.33) single crystals grown by the self-flux method. X-ray diffraction, transport, and magnetic measurements were performed for purposes of characterization. X-ray analysis revealed that the c lattice parameter systemically decreases as the Y doping level increases. The superconducting transition temperature T-c decreases from 80 to 30 K as x increases. A strong annealing effect on T-c and superconducting volume has been observed. Resistance measurements show that x = 0.33 samples are semiconductive over a wide temperature range between 4.2 and 300 K for the as-grown state, but become metallic with T-c of 65-70 K after air or oxygen annealing. Flux pinning was studied by measuring the hysteresis loop at different temperatures and different fields. A peak effect was observed in all the co-doped samples. Results show that at low temperatures, the peak field is smaller than in solely Pb doped crystals and decreases as x increases (x > 0.1). However, the peak field at high temperature for the x = 0.05 sample is higher than in heavily Pb doped Bi2212 crystals, indicative of a strong pinning due to the codoping.

Spin glass state in Gd2CoMnO6 perovskite manganite, Solid State Communications 118(1):27-30, (2001)

X.L. Wang, J. Horvat, H.K. Liu, A.H. Li and S.X. Dou

Dc magnetisation and ac susceptibility were measured on Gd2CoMnO6 perovskite manganite synthesised by solid state reaction in dc magnetic fields up to 5 T and an ac magnetic field of 1 Oe at frequencies of 21, 217 and 2000 Hz over a wide temperature range from 300 K down to 4.2 K. A spin glass transition with a very sharp transition width of 1 K at temperatures as high as 112 K was observed after the paramagnetic to ferromagnetic transition. An antiferromagnetic transition occurs at 43 K, far below the spin glass state. The spin glass transition temperature is totally suppressed at a field of 5 T

Very fast formation of superconducting MgB2/Fe wires with high J(c), Physica C. 361(3):149-155 (2001)

X.L. Wang, S. Soltanian, J. Horvat, A.H. Li, M.J. Qin, H.K. Liu and S.X. Dou

In this paper, we have investigated the effects of sintering time and temperature on the formation and critical current densities of Fe-clad MgB2 wires. MgB2 wires were fabricated using the powder-in-tube process and sintered for different periods of time at predetermined temperatures. All the samples were examined using XRD, SEM, and magnetisation measurements. 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. The results from T-c,J(c) and H-irr show convincingly that the samples which were sintered for 3 min above 800 degreesC are as good as those sintered for longer times. In fact, the J(c) field performance for the most rapidly sintered sample is slightly better than for all other samples. J(c) of 4.5 x 10 (5) A/cm (2) in zero field and above 10 (5) A/cm (2) in 2 T at 15 K has been achieved for the best Fe-clad MgB2 wires. As a result of such a short sintering there is no need for using high purity argon protection and it is possible to carry out the heat treatment in a much less protective atmosphere or in air. 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.

Segregation growth of Bi-2(Sr,Ca)(2)CuOy single crystals by using self-fluxes, Journal of Materials Science Letters. 20(15):1455-1457 (2001)

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

Large good quality Bi-2201 crystals have been grown using a starting composition used for growing Bi-2212, but different growth conditions. Rapid cooling imposed at the beginning of crystal growth prevents the formation of Bi-2212 crystals, but large size Bi-2201 single crystals are grown through a segregating process. Crystals with dimensions of 10 x 4 mm^2 in the ab plane were obtained. X-ray diffraction, scanning electron microscopy, and optical microscopy were used to characterize the crystals. The compositions of as-grown crystal were determined to be Bi:(Sr,Ca):Cu=2:(1.8,0.2):1. Unlike Bi-2212 crystals, the as-grown Bi-2201 crystals were difficult to cleave and showed a very rough surface after cleavage, indicating stronger biding between BiO layers than in Bi-2212 crystals.

Study of the peak effect in pure, Pb and Pb+Y doped Bi-2212 single crystals, Physica C. 364:622-625 (2001)

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

The peak effect (PE) in pure, Pb and Pb + Y doped Bi2212 single crystals with different oxygen doping levels was studied by measuring M-H loops over a wide temperature range. The PE in pure Bi2212 crystals was obtained only for crystals with optimal oxygen doping and over-doping but not observed for oxygen under-doped crystals. For Pb doped Bi2212 crystals, the PE appeared at a higher field than in the pure crystals and persisted up to T-c. For (Bi1.64Pb0.36)Sr2Ca1-xYxCu2O8+y (x = 0. 0.05, 0.11, 0.33) single crystals. Results show that at low temperatures. The peak field is smaller than in solely Pb doped crystals and decreases as x increases (x > 0.1). However, the peak field at high temperature for the x = 0.05 sample is higher than for heavily Pb doped Bi2212 crystals. Indicative of strong pinning due to the co-doping. The formation of Bi5+ rich clusters, which cause the reduction of the c-axis lattice parameter and ρ_c is proposed to be responsible for the appearance of the PE in the undoped crystals. The co-existence of Pb4+ - and Bi5+-rich clusters causes the strong PE in Pb doped Bi2212 crystals. Y3+ is proposed to be an effective dopant at low doping levels for flux pinning at high temperatures.

The PE for all the crystals was characterised by plotting (H-max - H-min)/H-max vs T/T-c, where H-min and H-max represent the fields at which the magnetisation starts to increase (H-min) and reaches a maximum (H-max) at the peak position. Results showed that the evolution of the peak effect with temperature in the Pb and Pb + Y doped crystals was similar to that seen in Y123.

Sintering-temperature Dependence of Magnetization in $La_{0.67}Ba_{0.33}MnO_{3-\delta}$ Oxides, Materials Chemistry and Physics 75, 136 (2002)

Y.B. Zhang, S. Li, P. Hing and S.X. Dou;

The effects of microstructure on magnetization of $La_{0.67}Ba_{0.33}MnO_{3-\delta}$ manganites are investigated in the present work. It was found that the manganites have different grain-growth patterns, which strongly depend on sintering temperature. The $La_{0.67}Ba_{0.33}MnO_{3-\delta}$ manganite sintered at 1573K exhibited a lateral growth pattern while the manganite sintered at 1673K grew with a concentric terrace pattern. These resulted in various magnetic properties of the $La_{0.67}Ba_{0.33}MnO_{3-\delta}$ manganite. The manganite sintered at 1673K showed nearly four times as high as magnitude of magnetization and fairly high low-field susceptibility at low temperature compared to the one sintered at 1573K. It implies that the microstructures resulted by the different grain growth behaviors may strongly influence magnetoresistance effects.

Observation of Heat Flow at Transition Temperature in $La_{1-x}Ca_xMnO_{3+\delta}$ Oxides, J. Appl. Phys. 90 (9), 4583 (2001).

Y. B. Zhang, S. Li, C.Q. Sun, W. Gao, S.X. Dou and P. Hing

Heat-flow changes of $La_{1-x}Ca_xMnO_{3+\delta}$ (x = 0.25, 0.33, 0.375) magnetoresistive oxides at their Curie temperatures have been detected using differential scanning calorimetry (DSC) in the temperature range from 173K to 293K. However, the transition does not occur in the samples of x = 0.125 and 0.5. It was found that the heat flow reflected the transition behavior and the enthalpy change of the transition decreased as the transition temperature increased. These results indicate that the $La_{1-x}Ca_xMnO_{3+\delta}$ oxides (x = 0.25, 0.33, 0.375) undergo an endothermic phase transition from a low-temperature ferromagnetic metal to a high-temperature paramagnetic insulator. It is believed that the transition is strongly associated with a local structure change, which is correlated with the metal-insulator transition.

Thermal Transition Behaviour of $La_{2/3}Ca_{1/3}MnO_{3+\delta}$ Oxides, Solid State Communications 120, 107 (2001)

Y.B. Zhang, S. Li, P. Hing, C.Q. Sun, W. Gao and S.X. Dou;

Extraordinary thermal transitions of the $La_{1-x}Ca_xMnO_{3-\delta}$ (x = 0.25, 0.33, 0.375) ceramic oxides have been found using differential scanning calorimetry (DSC) in the temperature range from 293K to 173K. However, such a transition does not occur in the samples of x = 0.125 and 0.5 in the broader temperature range from 293K to 123K. Interestingly, the thermal transition temperature reflects Curie temperature and the enthalpy change of the transition varies inversely proportional to the transition temperature. These results indicate that the $La_{1-x}Ca_xMnO_{3-\delta}$ (x = 0.25, 0.33, 0.375) oxides undergo a first-order exothermic phase transition from a high-temperature paramagnetic insulator to a low-temperature ferromagnetic metal. It is suggested that the transition result from a local lattice structure change, which is correlated with lattice distortion.

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

Sihai Zhou, Alexey V. Pan, Mihail Ionescu, Huakun Liu, and Shixue 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.

Energy Storage Materials Group

Graphite-Tin Composites as Anode Materials for Lithium-ion Batteries, Journal of Power Sources 97-98 (2001) 211-215

G. X. Wang, Jung-Ho Ahn, M. J. Lindsay, L. Sun, D.H. Bradhurst, S.X. Dou and H.K. Liu

Graphite-tin composites were produced by high-energy ball-milling. X-ray diffraction and HREM observation showed that graphite became amorphous and tin became nanocrystalline after the intensive ball milling. The element Sn was encapsulated in the ductile graphite matrix on a nanometer scale. Electrochemical tests show that the lithium storage capacity increases with the addition of Sn, which could be attributed to the reaction of Sn with Li to form Li_xSn alloys. The volume expansion due to the alloying process may be buffered by the amorphous graphite matrix. The $C_{0.9}Sn_{0.1}$ electrode can deliver a discharge capacity of 1250 mAh/g in the initial cycle. Generally, the capacity of the ball milled C, $C_{0.9}Sn_{0.1}$ and $C_{0.8}Sn_{0.2}$ electrodes decrease with cycling quite quickly, but the $C_{0.9}Sn_{0.1}$ and $C_{0.8}Sn_{0.2}$ electrodes have better cyclability than that of the ball milled graphite electrode. The combination of C and Sn could be an anode material with high capacity for lithium ion batteries.

An Investigation of Cobalt Oxides as Anode Materials for Li-ion Batteries, Journal of Power Sources 2002 (in press)

G.X. Wang, Y. Chen, K. Konstantinov, 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.

Nanosize Cobalt Oxides as Anode Materials for Lithium-ion Batteries, Journal of Alloys and Compounds 2002 (in press) (Letter to Editor).

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.

Multiple ions doped lithium nickel oxide as cathode materials for lithium-ion batteries, 11th International Meeting on Lithium Battery, USA, 2002

G.X. Wang, K. Konstantinov, Jane Yao, Steve Bewlay, Y. Chen, H.K. Liu and S.X. Dou

Lithium-ion batteries are the state-of-the-art power sources for modern portable electronic devices. They have the highest energy density and longest cycle life among all kinds of rechargeable batteries. The electrochemical properties of cathode materials in lithium-ion batteries are very critical for the overall battery performance. Three classes of materials eg. $LiCoO_2$, $LiNiO_2$ and $LiMn_2O_4$ compounds have been developed as cathode materials for lithium-ion batteries. Among of them, the structurally ordered $LiNiO_2$ compounds are difficult to synthesize and their cyclability is very poor. $LiMn_2O_4$ spinels have low specific capacity and are structurally unstable for lithium ion intercalation and de-intercalation. In practical, only $LiCoO_2$ compound is widely used as cathode materials in commercial lithium-ion battery production. However, $LiCoO_2$ compounds are expensive and not environmentally benign due to the toxicity of cobalt. Therefore, it is necessary to develop new cathode compounds for lithium-ion batteries, which are cheaper, non-toxic and have good electrochemical performance. The strategy is to replace cobalt with other ions. The structural integrity must be kept so that the electrochemical properties can be maintained. Such new cathode materials are crucial for making large-scale lithium-ion batteries for electric vehicles and stationary energy storage application.

In this investigation, a series of multiple ions doped lithium nickel oxides were synthesized via solid-state reaction. The pure phase $LiM_xM'_yNi_{1-x-y}O_2$ compounds with layered structure were obtained. The structure of $LiM_xM'_yNi_{1-x-y}O_2$ compounds were analyzed and fitted by a Rietveld program. Fig. 1 shows a typical X-ray diffraction pattern of a $LiM_xM'_yNi_{1-x-y}O_2$ compound. The electrochemical properties of the as-prepared $LiM_xM'_yNi_{1-x-y}O_2$ compounds were systematically tested. Typical $LiM_xM'_yNi_{1-x-y}O_2$ cathodes can deliver a capacity in the range of 140 – 180 mAh/g with stable cyclability. Fig. 2 shows the charge / discharge curves of a $LiM_xM'_yNi_{1-x-y}O_2$ electrode. The doped $LiM_xM'_yNi_{1-x-y}O_2$ compounds demonstrated the same voltage behaviours as $LiCoO_2$ compound. The $LiM_xM'_yNi_{1-x-y}O_2$ compounds are promising candidate to replace $LiCoO_2$ as cathode materials for lithium-ion batteries.

Physical and Electrochemical Characterization of $LiNi_{0.8}Co_{0.2}O_2$ Thin Film Electrodes Deposited by Laser Ablation, Journal of Power Sources 97-98 (2001) 298-302

G. X. Wang, M. J. Lindsay, M. Ionescu, D. H. Bradhurst, S. X. Dou and H. K. Liu

The thin film electrodes of $LiNi_{0.8}Co_{0.2}O_2$ were deposited by pulsed laser ablation. The average thickness of these thin films was measured by AFM to be approximately 0.62 μm. The electrochemical properties of $LiNi_{0.8}Co_{0.2}O_2$ thin films as working electrode in lithium cells were characterized by galvanostatic charge/discharge, cyclic voltametry and a. c. impedance spectroscopy. The average capacity of these thin-film electrodes is about 60 – 62.5 $\mu A/cm^2.\mu m$. The Li^+ diffusion coefficient in the $LiNi_{0.8}Co_{0.2}O_2$ thin film electrode was measured to be in the range of $3.19 * 10^{-13}$ - $2.48 * 10^{-10}$ m^2s^{-1}.

Preparation and Characterisation of Carbon Nanotubes for Energy Storage, 11th International Meeting on Lithium Battery, USA, 2002

G.X. Wang, Jane Yao, Matthew Lindsay, Y. Chen, H.K. Liu Jung-ho Ahn, S-H. Ryu

Carbon nanotubes (CNTs) were discovered by Iijima, who produced helical microtubules of graphitic carbon using an arc-discharge evaporation method. Since then, tremendous interest and effort have been devoted to the production, characterisation and application of carbon nanotubes. In general, carbon nanotubes can be classified as two catagories eg. multiwalled carbon nanotubes (MWNTs) and single wall carbon nanotubes (SWNTs). Since various carbonaceous materials can reversibly react with lithium in Li-ion cell, carbon nanotubes have been speculated to the applications as lithium storage materials in Li-ion batteries. It has

been reported that carbon nanotubes demonstrated reversible lithium storage capacity in the range of 80-600 mAh/g. The electrochemical performance of carbon nanotubes strongly depends on their structure, morphology and disorder.

In this investigation, multiwalled carbon nanotubes were produced using the catalysts with nano size particles by chemical vapor deposition (CVD). Fig. 1 shows the HRTEM image of the carbon nanotubes. 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. Fig. 2 shows a cyclic voltammetry of carbon nanotube electrode in lithium-ion cell. 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.

The Application of Carbon Nanotubes as Anode Materials in Li-ion Batteries, Journal of Metastable & Nanocrystalline Materials 2002 (in press)

G.X. Wang, Jane Yao, Matthew Lindsay, Y. Chen, H.K. Liu Jung-ho Ahn, S-H. Ryu

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.

Electrochemical Performance of Nanocrystalline Lead Oxide in VRLA Batteries

J. Wang, S. Zhong, G.X. Wang, D.H. Bradhurst, M. Ionescu, H.K. Liu, and S.X. Dou

Nanocrystalline lead oxide was prepared through two-step chemical reactions and has been tested as the electrode active material for the valve-regulated lead acid (VRLA) battery. By using this nanocrystalline lead oxide, the pasted electrodes can be directly formatted without a curing process. The initial specific capacity of the new electrode was 30% higher than that of the electrode with the conventional ball-milled leady oxide and the cycle behaviour of the new electrode was also improved.

Solid State Physics Group

Far-Infrared Spectroscopy of the Zinc Acceptor in Indium Phosphide

R. L. Causley and R. A. Lewis

We report the absorption spectrum of Zn acceptor in InP. Fourier interferometers equipped with Si bolometers were used to collect spectra at sample temperatures down to 1.9 K. Zeeman measurements were made in the Voigt configuration at fields up to 6.5 T with the electric field of the radiation, $\boldsymbol{E}$, polarised either parallel or perpendicular to the magnetic field, $\boldsymbol{B}\|\langle 001\rangle$. Energies for the *G* and *D* lines, corresponding to transitions from the $1s_{3/2}(\Gamma_8^+)$ to the $2p_{3/2}(\Gamma_8^-)$ and $2p_{5/2}(\Gamma_8^-)$ states, respectively, are 241.5±0.2 cm^{-1} and 286.0±0.2 cm^{-1}, respectively. Data taken at higher resolution (0.05 cm^{-1}) indicate an intrinsic line width of 0.5 cm^{-1} (FWHM) for a carrier concentration of 4×10^{16} cm^{-3}. At low magnetic field ($B < 3$ T), the *D* line rapidly broadens, losing intensity and becoming unresolvable. At the highest fields, four components for $\boldsymbol{E}\|\boldsymbol{B}$ and two for $\boldsymbol{E}\perp\boldsymbol{B}$ are resolved for the *G* line. Comparing data at 1.9, 2.9, 5.4 and 10.4 K reveals thermal depopulation

effects. These experimental data permit determination of *g*-factors for the ground and first excited state of Zn in InP.

Electronic States and Dielectric Response of an Electron Gas under a Quantizing Magnetic Field and an Intense Laser, (Computer Physics Commun. 142 374 (2001))

C. Zhang

By constructing successive unitary transformations, we have solved the time-dependent Schrodinger equation for an electron gas under a quantizing magnetic field and an intense laser. This wavefunction is then employed to calculate the electronic Green' s function, polarizability and the dynamic dielectric function. We have computed the frequency and intensity dependent dielectric functions and the spectrum of collective excitations of an electron gas under an intense terahertz radiation. The results show the effect of various multiphoton processes.

Resonant tunneling and bistability in a double barrier structure under an intense terahertz laser, (Appl. Phys. Lett. 78, 4187 (2001))

C. Zhang

By using exact wavefunctions of an electron in a terahertz laser field, we calculated the electron resonant tunneling through a double barrier structure.It is found that the laser field has two effects on the current voltage characteristics. Firstly, it introduces additional states in the resonant tunneling. Secondly, it reduces the width of the bistable region. At high field strength and low frequencies, the bistability can be completely removed. This can provide a method to probe the internal properties of the third state previously inside the bistable region.

Electronic thermal transport and thermionic cooling in semiconductor multi-quantum-well structures, (Computer Physics Commun. **142**, 274 (2001))

B. Lough, S. P. Lee, R. A. Lewis and C. Zhang

Recently, it has been proposed that semiconductor or metal-semiconductor multilayer systems can be used as energy generator or cooling devices based on the principles of thermionic emission. Such thermionic cooling devices will have much higher figures of merit than thermoelectric devices. Multilayer thermionic structures have advantages of reduced phonon transport and thus increased thermal efficiency. In this work we present a numerical investigation of the electronic thermal transport in multilayer systems. The figure of merit for different multilayer structures is calculated and optimised to give bias and temperature as a function of work function of the material.

Electronic states and dielectric response of a two-dimensional electron gas in a strong magnetic field and an intense laser field, (Physica B **298**, 333 (2001))

C. Zhang and W. Xu

We have developed new theoretical and numerical methods to study electronic properties and dielectric response of an electron gas strongly coupled to a terahertz laser field and under a quantisising magnetic field. By constructing successive unitary transformations, we have solved the time-dependent Schrondinger equation and obtained analytical solutions of the electronic wavefunction. These wavefunctions are then used to construct the electronic Green' s function, density-density correlation function and the dielectric response function in time and spectral representations. Our results can be the basis for studying several other important quantities related to the experiments such as optical absorption, spectrum of magneto-polaritions and cyclotron resonances in stongly coupled electron-photon systems. Numerical results of energy loss rate of a heavy particle based on this dielectric function are presented.

Dynamical Franz-Keldysh effect of an electron gas in high magnetic fields and intense laser fields, (Physica B 298, 339 (2001))

W. Xu and C. Zhang

When an electron gas is subjected simultaneously to quantizing magnetic fields and intense laser fields in Faraday geometry, the electron density of states and the fundamental absorption edge will be shifted by an energy $E_{em}=(eF_0)^2/[4m^*(\omega^2-\omega_c^2)]$, where ω and F_0 are respectively the frequency and the electric field strength of the laser field and ω_c is the cyclotron frequency. This is known as dynamical Franz-Keldysh effect (DFKE). In this paper, we study theoretically the DFKE for a semiconductor-based electron gas system in the presence of quantizing magnetic fields and of intense terahertz (THz) laser fields.

Transport in quantum-dot lattices in a periodic magnetic field, (Proc. 25th Int. conf. Phys. Semicond., Springer Proceedings in Physics **87**, 1095 (2001)).

G. Gumbs, C. Zhang and R. Vickers

The static magnetoconductivity σ_{yy} is calculated as a function of temperature for a square lattice with period *a* in a periodically modulated magnetic field (PMMF) with period *b*. We develop a magneto-transport theory for a periodic magnetic field $B_1\sin(2\pi x/b)$. The energy eigenvalue spectra are presented as a function of the magnetic field for different values of the commensurability ratio between the period of the lattice and the period of the magnetic modulation. Our model permits us to predict anomalies, such as the appearance of metal-insulator transition at low temperatures. This M-S transition originates from contributions to the conductivity due to the eigenstates whose energies are in the vicinity of the Fermi energy.

Numerical calculation of thermionic cooling efficiency in a double barrier semiconductor heterostructure**,** (Physica E **11**, 287 (2001))
B. C. Lough, S. P. Lee, R. A. Lewis, and C. Zhang

Exact numerical calculation of the thermionic cooling efficiency of single barrier and double barrier structures are presented. The single barrier structure becomes more efficient as the temperature difference is decreased. The maximum efficiency of the double barrier system is less than that of the single barrier system.

Current & Ongoing Research Projects

ARC Large/Discovery Grants Scheme

Investigation of growth mechanism and flux pinning in spiral-grown Bi-High temperature superconducting single crystals

Funded:	1999	2000	2001
Amount funded:	$60,932	$61,989	$62,000
Chief Investigator:	SX Dou		
Assoc. Investigator:	J. Horvat, E.W. Collings, V. Pan		
Research Fellow:	X.L. Wang		
Postgrad. Students:	K. Uprety, F. Gao		

Research aims to investigate a new growth mechanism and the influence of associated screw dislocations on crystal characteristics of doped and un-doped $Bi_2Sr_2CaCu_2Oy$ & $Bi_2Sr_2Ca_2Cu_3Oy$ monocrystals. Comparative studies of crystals grown using different procedures, including the complex flux technique, co-doping, nanorod inclusions and irradiation, will lead to better understanding of the pinning behaviour of Bi-based HTSCs. It is expected that the research outcome will be identification of methods for introducing effective pinning centres into Bi:HTSC in order to raise critical current density to a suitable level for applications.

Cryogenic deformation & high Tc phase transformation-partial decomposition of superconducting tapes

Years funded:	1999	2000	2001
Amount funded:	$60,000	$60,000	$62,000
Chief Investigator:	H.K. Liu		
Assoc. Investigator:	S.X. Dou, B. Zeimetz		
Postgrad. Students:	X.K. Fu,		

This proposal presents two novel concepts: cryogenic processing and high Tc phase formation-partial decomposition for processing high temperature superconducting (HTSC) materials. The aim is to investigate the mechanisms of these two processes and their effect on microstructure, critical current density (Jc) and flux pinning behaviour of Ag-clad Bi(Pb)SrCaCu tapes. The associated critical issues including the formation mechanism of $(Bi,Pb)_2Sr_2Ca_2Cu_3O_{10}$, Pb distribution and Ag addition in the precursor powder, will also be addressed and clarified through comparative studies on various forms of the same HTSC compounds. A new approach will be proposed to take advantage of cryogenic processing, 2223 formation-partial decomposition and hot deformation.

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. Marinara, 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 Jc 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,				
Partner 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.

ARC Research Fellowships

Doping of Silver-Alloy Sheath of Bi-HTS wires

Years funded: 1998 -1999 -2000 (ext to June 2001)
Amount funded: $174,000
Chief Investigator: Y.C. Guo, Postdoctoral Research Fellow

A novel wire processing technique, called 'the Continuous Tube Forming/Filling (CTFF)' procedure will be developed, which will enable the continuous fabrication of fine, very uniform and extremely long Bi2223 wires directly from powder. This new manufacturing process aims to overcome the process-induced inhomogeneities encountered in the conventional PIT method. In order to reduce heat treatment-induced inhomogeneities, a 'defined phase balance' precursor powder will be used to fabricate superconducting wires and tapes instead of normal multiphase precursor powder and the heat treatment conditions will be optimised during heat treatment. In order to increase the strength of the composite wires and tapes, a series of silver-based alloys will be evaluated as sheath material to replace pure silver.

The effect of the various alloy sheath materials on the electrical and mechanical properties of Bi2223 wires and tapes will also be investigated. Finally, with the combination of CTFF processing, 'defined phase balance' precursor powder and strength-enhanced alloy sheath materials, long and uniform Bi2223 tapes with properties suitable for practical applications will be fabricated.

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	$95,278
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 $(Bi,Pb)_2Sr_2Ca_2Cu_3O_{10}$ (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-decompositon 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 B:2223 tapes, making them suitable for applications.

Generation of coherent-hypersound from semiconductor systems

Years funded:	2001	2002	2003	2004	2005
Amount funded:	$72,276	$74,406	$76,534	$78,665	$80,792
Chief Investigator:	W. Xu, ARC Research Fellow				

Coherent-hypersound is an entirely new source of high frequency ultrasound with a pure frequency and coherent nature. It can be extensively applied in industry, medical treatment and scientific research, especially in ultrasonic and electronic devices. This project will investigate the generation and propagation of coherent-hypersound with frequency~1 terahertz using state-of-the-art semiconductor and laser technique. It is intended to study theoretically the coherent- hypersound generation via emission of coherent-phonons in GaAs- and GaN-based systems, in conjunction with different experimental techniques. This project will be carried out in collaboration with local and international experimental groups.

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		

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.

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

Effective transverse matrix resistivity of multifilamentary BiHTSC/Ag tapes in response to variation of strand architecture and processing method

Years funded:	1999	2000	2001
Amount funded:	$90,687	$94,442	$77,000
Chief Investigator:	S.X. Dou		
Partner Investigator:	T. Beales, E.W. Collings		
Research Fellow:	J. Horvat		
Postgrad. Students:	F. Darmann		
Industry Partner:	Metal Manufactures Ltd		

Multifilamentary (MF) high temperature superconductor tapes are being manufactured for numerous DC and AC applications. However in an AC environment the MF tape is subject to eddy current loss. The purpose of the proposed research is therefore to combine experiment and theory in order to show quantitatively the influence of: (a) external strand shape; and (b) internal filament architecture, on the hysteretic and eddy-current loss components of multifilamentary Bi:HTSC/Ag strands. Armed with the results of this research we hope that it will be possible for the first time, to design MF HTSC ribbons with pre-determined levels of AC loss.

Substrates for large-area Y-123 films obtained by pulsed laser deposition

Years funded:	1999	2000	2001
Amount funded:	$21,000	$21,000	$21,000
Chief Investigator:	J. Horvat / M. Ionescu		
Partner Investigator:	M. Apperley		
Postgrad. Students:	J. McKinnon		
Industry Partner:	Metal Manufactures Ltd		

Current carrying capabilities of high-temperature superconductors are critically dependent on the connectivity of superconducting grains, which is much better for thin films than for other types of superconductors. One of the main limitations in growing large area films is the preparation of suitable substrates onto which the films will be grown. Ideally, the substrate would perfectly match the superconductor's crystalline lattice and be perfectly textured. Surprisingly, some porous substrates can also give high quality films. The aim of the project is to answer why this is so. Knowing this, it may be much easier to prepare large substrates, opening the door to thin films of large size.

Reduction of heat leak of high Tc superconducting current leads

Years funded:	1999	2000	2001
Amount funded:	$80,976	$85,314	$77,632
Chief Investigator:	H.K. Liu		
Partner Investigator:	M. Apperley		
Assoc. Investigator:	B. Zeimetz, T. Chandra		
Research Fellow:	R. Zeng		
Postgrad. Student:	Z.M. Zhang		
Industry Partner:	Metal Manufactures Ltd		

The aim of the proposed project is to bring together expertise from UoW's HTS research group and the research and production group at MM Cables HTS Development Facility to study reduction of the heat leak from HTS current leads. The project will focus on minimisation of thermal conductivity using alloyed silver, large silver particle doping and improvement of conductor design on the one hand, and on maximising J_c by adopting optimised processing parameters on the other. Critical issues including general design formulas, effects of thermal cycling on the current leads and transient behaviour in the temperature profile of current leads will be addressed. The outcomes of this research will allow us to design Ag alloy-sheathed HTS current leads with a minimum heat loss, which will ensure greater energy savings and resource conservation.

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.

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:	J. 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).

Linkage Projects & Linkage APAI

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		
Assoc. Investigators:	Dr G Wang, Prof J Lee		
Research Fellow:	K. Konstantinov		
APA(I) Award(s):	S. Bewlay		
Industry Partner(s):	Queensland Nickel Technology Pty Ltd (A Division of Billiton)		
	Sons of Gwalia Ltd		

This project will bring together expertise in electrochmistry, 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 resourecs. The expected outcomes will be to identify several new cathode materials with high energy density, long cycle life, low toxity 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		
Assoc. Investigators:	Dr XL Wang Dr M Ionescu A/Prof MD Sumption		
APA(I) Award(s):	C.B. Cai		
Industry Partner(s):	Alphatech International		
	The Hyper Tech Research Inc.		

The newly discovered superconductivity at 40K in magnesium diboride (MgB2) 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 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 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		
Assoc. Investigators:	Dr S Zhong A/Prof J Ahn		
APA(I) Award(s):	Y. Zhao		
Industry Partner(s):	Sons of Gwalia Ltd		
	QNI Technology Pty 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 (MgB2) 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):	vacant		
Industry Partner(s):	SFC Enterprises Pty Ltd		

The recent discovery of superconductivity at 39 K in MgB2 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 MgB2 thick films. The ultimate goal of this study is to fabricate high quality MgB2 thick films on different substrates and to gain a better understanding of their various properties with a view to device application.

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	

The performance of modern electronic, microelectronic, optoelectronic and photonic devices improves as they are cooled. We aim to develop semiconductor cooling elements that can be directly integrated into existing circuits and devices. The new solid-state cooling elements will be reliable, robust, and scalable, and operate in any orientation. 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. The outcome of this research has the potential to revolutionize cooling of diverse electronic systems, from computer motherboards to mobile phones.

Investigation of a series of metallic sustrate 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.

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 $LiCoO_2$. The aim of this project is to develop new composite cathode materials by using a $LiCoO_2$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

High resolution scanning magnetic microscope

Years funded:	2001
Amount funded:	$400,000
Chief Investigators:	S.X. Dou, R.A. Lewis, H.K. Liu, Y.B. Cheng, R. Krishnamurthy, R. Ramer J. Mazierska, T. Beales
Collaborating Universities:	Monash University, University of New South Wales, James Cook University Australian Superconductors

The high resolution scanning magnetic microscope (HRSMM) is an extremely sensitive near-field imaging system for measuring local magnetic fields. It uses a small, high transition temperature Superconducting Quantum Interference Device as the sensor. It senses magnetic fields down to a field about two million times weaker than Earth' s magnetic field. The HRSMM has wide ranging applications from fundamental research to practical applications in electronic industries. The system can be used to determine the location of short circuits in multi-chip modules or microelectronic circuits, to image rf and microwave magnetic fields from circuits and to detect cracks in superconducting wires and small metal parts by eddy-current imaging .It can also be used to study current limiting mechanisms and vortex configurations in superconductors and detect new magnetic and superconducting materials.

Electrochemical mapping facility

Years funded:	2001
Amount funded:	$180,000
Chief Investigators:	G. Wallace, H.K. Liu, L. Kane-Maguire, G. Spinks
Collaborating Universities:	University of Western Sydney

This proposal seeks to provide advanced state-of-the-art electrochemical equipment, unprecedented in Australia, for researchers at the University of Wollongong and the University of Western Sydney. The equipment will make possible the identification and mapping, at hitherto unobtainable resolution (down to the micron level), of electrochemical processes occurring at the surfaces of a wide range of advanced materials under active development in our laboratories. These materials have a variety of potential applications such as new corrosion-protection coatings, highly selective and sensitive chemical and biochemical sensors, and advanced electrodes for high energy batteries. The equipment will also enable us to undertake exciting new projects such as the assembly of micromachines and microarray systems.

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.

International Research Exchange Program (IREX)

Investigation of novel metal nickel hydride electrode for rechargeable batteries

Years funded: 2001
Amount funded: $87,178
Chief Investigator: S.X. Dou / J.H. Ahn

Magnesium-nickel alloy has the highest hydrogen storage capacity, lowest cost and least pollution among all of the hydrogen storage materials. However, the slow kinetics of hydriding is a stumbling block in application of this material to rechargeable batteries. The aim of the proposed project is to improve our understanding of the electrode process in new types of rechargeable batteries.

The expected outcomes will contribute to the growing science and technology of rechargeable battery materials, enhancing the Australian manufacturing capability in metal hydride materials. Prof. J.H. Ahn from Andong National University has a world reputation and unique expertise in processing intermetallic materials and will make a significant contribution to the existing collaborative project.

Phase Equilibrium diagram of Ag/Bi203-PbO-SrO-CaO-CuO System

Years funded: 2001
Amount funded: $62,424
Chief Investigator: H.K. Liu / P. Majewski

This project will enhance the strong collaboration between researchers from the University of Wollongong and Max –Planck Instit f. Metallforschung, Stuttgart, Germany, established on the basis of High Temperature Superconductors (HTS) research. Silver (Ag) is widely used as a sheath material for the processing of Bi-based superconducting wires and tapes used for high electric current cables.

Profs. Liu and Majewski are interested in the investigation of the phase relations, the Pb solubility, and the crystallisation of the high Tc (transition temperature) phase from the melt when Ag is present. Experiments on the crystallisation of the high Tc phase out of the melt including Ag will be performed and the collaboration will be continued.

ARC Small Grants Scheme

The development and fundamental study of new lithium-ion battery systems

Years funded: 2001
Amount funded: $10,000
Chief Investigators: D. Bradhurst, S. Zhong
Assoc. Investigators: H.K. Liu

An advanced battery charging technique and related apparatus for electric vehicles

Years funded: 2001
Amount funded: $10,000
Chief Investigators: S. Zhong, S.X. Dou
Assoc. Investigators: D. Bradhurst

Improvement of surface quality of Y-123 high T_c superconducting thin film produced by pulsed laser deposition

Years funded: 2001
Amount funded: $9,000
Chief Investigators: M. Ionescu

Preparation and characterisation of advanced nano-crystalline oxide materials based on Australian mineral resources for application in Li-ion batteries

Years funded: 2001
Amount funded: $9,000
Chief Investigators: K. Konstantinov

Optical study of organic semiconductors

Years funded: 2001
Amount funded: $5,600
Chief Investigators: R.A. Lewis

Study of charge and spin ordering and colossal magnetoresistance in perovskite manganites

Years funded: 2001
Amount funded: $9,000
Chief Investigators: X.L. Wang

Department of Energy

Generic high temperature superconducting coils for AC power engineering applications

Years funded:	2000	2001
Amount funded:	$188,150	$50,370
Chief Investigator:	T. Beales, S.X. Dou, C. Cook	

Australian Institute of Nuclear Science & Engineering

Compensation of boron-doped silicon by neutron transmutation doping with phosphorus

Years funded:	2001
Amount funded:	$13,950
Chief Investigator:	P. Fisher

Implant of amorphous tracks in Bi-2212 thin films

Years funded:	2001
Amount funded:	$5,035
Chief Investigator:	M. Ionescu

Colossal magnetoresistance films grown by laser ablation

Years funded:	2001
Amount funded:	$5,740
Chief Investigator:	R.A. Lewis

Special Postgraduate Award

Years funded:	2001
Amount funded:	$6,550
Chief Investigator:	S.X. Dou
Postgraduate student:	D. Marinaro

Insitu structural studies of electrode materials for lithium batteries

Years funded:	2001
Amount funded:	$2,310
Chief Investigator:	D. Bradhurst

Australian Academy of Science

Scientific Visits to Europe

Years funded: 2000-2001
Amount funded: $4,931
Chief Investigator: R.A. Lewis

Free-electron laser investigations of semiconducting and magnetoresistive materials

Experiments were carried out at the Dutch Free-Electron Laser Facility "FELIX" over a two-week period and an allocation of 8 beam-shifts. A variety of electronic materials were investigated, including GaAs:Be, InP:Zn, GaAs/AlGaAs 2DEG and MgB_2. Wavelengths were employed in the range 40 - 110 μm, magnetic fields in the range 0 - 14 T, and temperatures in the range 4 - 300 K. The beam time was spent very productively with much useful data accruing.

University of Wollongong

University Research Council, ISEM Performance Indicator

Year funded: 2001
Amount funded: $145,900

Matching Scholarships

Phase formation and decomposition of high Tc superconductors

Years funded:	1999	2000	2001
Amount funded:	$8,100	$8,100	$8,100
Chief Investigator:	H.K. Liu		
Postgrad. Students:	D.Q. Shi		

Magnetisation and AC Loss of HTS

Years funded:	1999	2000	2001
Amount funded:	$8,100	$8,100	$8,100
Chief Investigator:	S.X. Dou		
Postgrad. Students:	K. Uprety		

CMR Materials

Years funded:	2000	2001
Amount funded:	$8,100	$8,100
Chief Investigator:	H.K. Liu	
Postgrad. Students:	E. Sotirova	

Density evolution during processing Bi-2223

Years funded:	2000	2001	2002
Amount funded:	$8,100	$8,100	$8,100
Chief Investigator:	H.K. Liu		
Postgrad. Students:	S.H. Zhou		

Thick Film of HTS

Years funded:	2000	2001
Amount funded:	$8,100	$8,100
Chief Investigator:	S.X. Dou	
Postgrad. Students:	A.H. Li	

Conference Presentations

3rd International Conference on New Theories, Discoveries and Applications of Superconductors and Related Materials, 15-19th January 2001, Honolulu, Hawaii, U.S.A.	
S. Soltanian, X.L. Wang, H.K. Liu, J. Horvat, T. Silver, S.X. Dou	Effects of Cr doping on the structure, charge ordering, transport and spin ordering state in $Nd_{0.5}Sr_{0.5}Mn_{1-x}Cr_xO_3$
X.L. Wang, H.K. Liu, S.X. Dou	Study of the peak effect in pure, Pb and Pb + Y doped Bi-2212 single crystals
25th Annual Condensed Matter Meting 2001, 30th January – 2nd February 2001, Marlborough Sounds, New Zealand	
R.L. Causley, R.A. Lewis	Zeeman spectroscopy of the zinc acceptor in indium phosphide
F. Gao, R.A. Lewis, X.L. Wang, S.X. Dou	Infrared absorption in a A2CoMnO6
R.A. Lewis, S. Lee, B.C. Lough, C. Zhang	Thermionic cooling based on semiconductor multi-layer structures
Advanced Research Workshop on Semiconductor Nanostructures, 5-9th February, 2001, Queenstown, New Zealand	
B.C. Lough, S. Lee, R.A. Lewis, C. Zhang	Numerical calculation of the thermionic cooling efficiency in a double-barrier semiconductor heterostructure
International Conference on Materials for Advanced Technologies, 1-6th July 2001, Singapore	
J. Wang, S. Zhong, G.X. Wang, H.K. Liu	A new plate making technique for VRLA battery manufacturing
J. Wang, S. Zhong, C.Y. Wang, G.X. Wang, H.K. Liu	Enhancing the specific capacity and performance of VRLA batteries using pure lead oxides
Z.P. Guo, G.X. Wang, H.K. Liu, S.X. Dou	Structure and electrochemistry of $LiCr_xMn_{1-x}O_2$ cathode for lithium ion batteries
C.Y. Wang, S. Zhong, J.Z. Wang, H.K. Liu, S.X. Dou	Structural study of aluminium stabilized alpha nickel hydroxide
X.L. Wang, H.K. Liu, S.X. Dou	Comparison studies of spiral growth mechanism in $Bi_2Sr_2CaCu_2OY$ and YBa_2Cu_3OY high temperature superconducting single crystals
A.H. Li, X.L. Wang, M. Ionescu, S.X. Dou	Growth and characterisation of $Bi_2Sr_2CaCu_2Oy$ thick films on rare polycrystalline Y-stabilised ZrO_2 substrate
E. Sotirova, X.L. Wang, J. Horvat, H.K. Liu	Study of structure, transport, paramagnetic and ferromagnetic properties $La_{0.8}Sr_{0.2}Mn_{1-x}Zn_xO_3$ perovskite manganite

S. Soltanian, X.L. Wang and S.X. Dou	Effects of grain size and grain boundaries on the transport and magnetic properties of charge-ordered $Nd_{0.5}Sr_{0.5}MnO_3$ material
X.L. Wang, H.K. Liu, S.X. Dou, G.D. Gu	The peak effect in Fe-doped Bi-2212 single crystals
Cryogenic Engineering Conference and International Cryogenic Materials Conference, 16-20th July, 2001, Madison, Wisconsin, U.S.A.	
M.J. Qin, X.L. Wang, S. Soltanian, H.K. Liu, S.X. Dou	Flux dynamics of MgB_2 superconductor by AC susceptibility measurements
D.Q. Shi, M. Ionescu, S.X. Dou	Relationship between orientation of cerium-oxygen2 buffer films and AFM morphology images
D.Q. Shi, M. Ionescu, S.X. Dou	Research of surface-oxidation epitaxy of NiO films on cubic Ni tapes
M. Ionescu, D. Shi, J. McKinnon and S.X. Dou	Study of outgrowth formation in CeO2 films deposited on YSZ<100> by PLD
E.W. Collings, M.D. Sumption, X.L. Wang, S.X. Dou	Ramp-rate dependence on the initial flux jump in a sintered slab of magnesium diboride superconductor
J. Horvat, M.M. Farhoudi	Transverse resistivity in unbridged Bi2223/Ag tapes
S.X. Dou, S. Soltanian, X.L. Wang, I. Kusevic, E. Babic, A.H. Li, M.J. Qin, J. Horvat, H.K. Liu, E.W. Collings, E. Lee, M.D. Sumption	High transport critical current density above 30K in MgB_2 tape with magnetic shielding
W.M. Chen, H.K. Liu, X.K. Fu, Y.C. Guo, D.Q. Shi and S.X. Dou	Effect of various mechanical deformation techniques on pinning force densities for Ag/Bi-2223 tapes
Physical Phenomena at High Magnetic Fields – IV, 19-25th October 2001, Santa Fe, New Mexico, U.S.A.	
R.A. Lewis, W. Xu, P.M. Koenraad, IV Bradley	Effect of strong terahertz radiation on the magnetoconductivity in two dimensions
R.A. Lewis, X.L. Wang, S.X. Dou, N. Biskup, J.S. Brooks	Ferromagnetic Resonances in polycrystalline La0.8Li0.2MnO3

Seminars by Visiting Scientists

Date	name	Institute	*Talk title*
10/5/01	Prof. E.H. Brandt	Max-Planck-Institut Fur Metallforschung, Stuttgart, Germany	The Peak Effect in the Magnetization of Type-II Superconductors
22/5/01	M. Skyllas-Kazacos	University of New South Wales	Recent developments with the vanadium redox battery and other energy storage technologies
30/5/01	Mr A. McDonagh	ATA Scientific, Australia	New Milling and Homogenising Process
13/6/01	Dr P. Majewski	Max-Planck-Institut fur Metallforschung, Stuttgard, Germany	Interaction between Bi-2223 as well as Bi-2212 and the Ag Sheath of Superconducting Tapes
20/6/01	Dr P. Majewski	Max-Planck-Institut fur Metallforschung, Stuttgard, Germany	(La,Sr) (Ga, Mg) O3 as Solid Electrolyte of Solid Oxide Fuel Cells
9/8/01	M. Das	Australian National University	When is a conductor not a metal?
2510/01	Prof. J Yau	Dept. Manufacturing Eng. & Engineering Management City University of Hong Kong	Microwave Sintering of High Temperature Superconductors
14/11/01	Dr L Li	Technical Institute of Physics & Chemistry Chinese Academy of Sciences	Magnetic Transport = GMR, MTJ and Magnetic Sensor
18/12/01	David Pointing	University of Tasmania	Is Hydrogen Ready for Antarcticia?
21/12/01	Prof. S. Ohshima	Faculty of Engineering, Yamagata University, Japan	Introduction to Bitter Technique for Observation Vortex; and Observation of Vortex Pattern and Movement of HTS Materials

Equipment and Facilities

ISEM facilities contain 9 laboratories with a floor space of approx 420m^2 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
Griffith University	Dr S Myhra
James Cook University	Prof. J. Majierska
Monash University	Dr S Ringer, Dr Y.B. Cheng Dr. R. Krishanmurthy
Queensland University of Technology	Dr P.D. Killen
RMIT	Prof PJK Paterson
University of Melbourne	D.N. Jamieson
University of NSW	Prof. G. Russell, Prof. C Grantham, Dr B Gleeson, Dr R. Ramer
University of Queensland	Prof. M.G. Lu, Prof D.R. Mackinnon
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 Depositon Chamber, 18" dia. With high vacuum system

Materials Characterisation

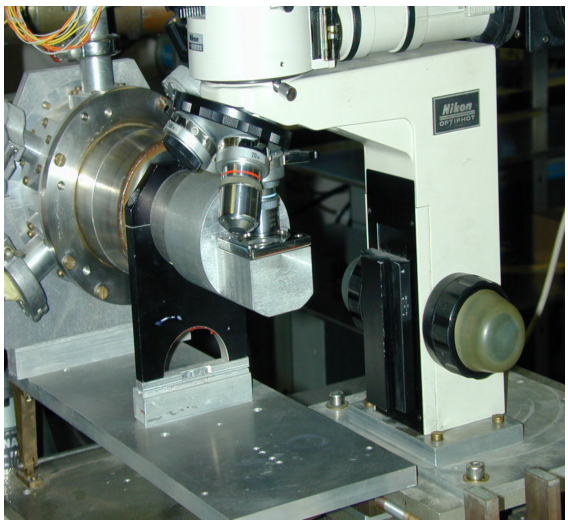
- DTA/TG, Setaram, 18-92, 1750°C
- XRD for Single Crystals
- TEM, J2000FX1, with EDS
- Gas absorption analyzer Nova 1000 for BET and pore size analyses
- XRD, M18XHFCu with HT 2000°C camera
- SEM, Stereoscan 440, with EDS and EBSP
- AFM, Nanoscope IIIa
- Particle Size Analyser, Mastersizer S, 0.05-900μm
- XRD, PW1050, 3kW; XRD Texture, PW1078, 3kW
- DSC, TA300,-170°C+600°C

Physical Property Characterisation

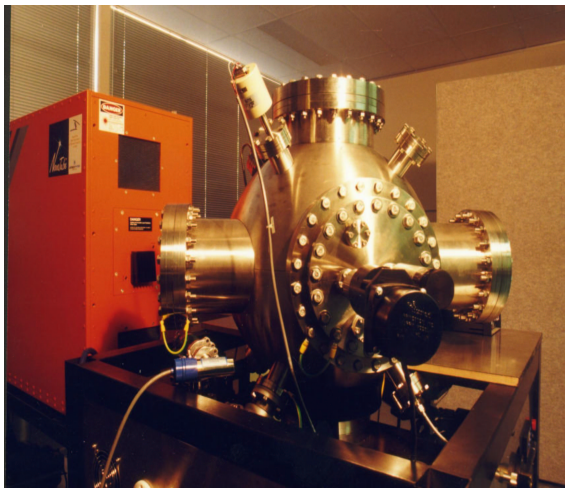
- MPMS, 4-400K, 0-5T DC field
- PPMS, 2-400K, 0-9T DC field
- Horizontal field superconducting Magnet, 0-8T, 5-300K
- Lock-in Amplifier, SR510; Lock-in Amplifier, SR830DSP, PAR 5209 Lock-in Amplifier, PAR 124 Lock-in Amplifier
- Magneto Optical Imaging, 12K-300K
- Electromagnet, HSV-4H1, 2T, 100mm pole 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, 2x4 inch iron-cored, Rawson-Lush gaussmeter
- Cantilever (torque force) magnetometer
- Various multimeters, HP and Keithley, including a nano-voltemeter
- 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
- 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 bolometers 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

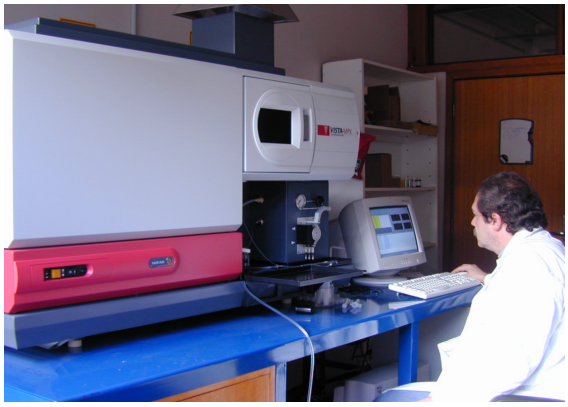
- Cyclic Voltammograph, BAS CV-27
- Impedance Analyser, M6310
- Temperature Controlled Water Bath, F10-MF
- Four Channels Data Collection System, MacLab/4e
- ICP-OES, Vista MPX simultaneous axial spectrometer, 167-785nm range 0.009nm resolution 200nm
- Scanning Potentiostat, M326; Potentiostat, M363
- 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



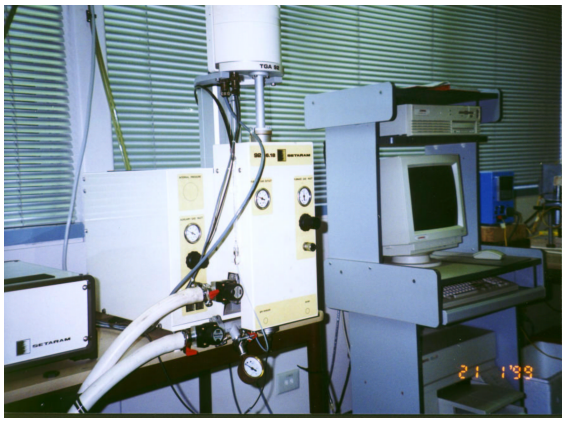
Magneto-Optical Imaging with
Cryocooler from 12K to 300K



Excimer Laser Ablation System for
Thin Film Deposition



ICP-OES, Vista Simultaneous
Axial Spectrometer



Simultaneous DTA/TGA to 1700°C

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

Glovebox for Creating Oxygen and Moisture
free Environment

Refereed Publications

HTS Program

J.H. Ahn, H.K. Liu and S.X. Dou, "Effects of oxygen partial pressure on processing conditions and phase transformation in Ag/Bi-2223 tapes" *Physica C* 351, 371-378 (2001)

E.Babic, I. Kusevic, D. Marinaro, S.X. Dou, J. Boldeman and R. Weinstein, "Vortex pinning by fission tracks in ^{235}U-doped Ag/Bi-2223 tapes", *Solid State Commun.***118**, 607-610 (2001)

E.H. Brandt "Geometric edge barrier in the Shubnikov phase of type II superconductors" *LowTemp. Physics* **27, No 9-10** 980-990 (2001)

C. Cai, H. Mori, H. Fujimoto, H.K. Liu and S.X. Dou, "Crystal growth patterns in MgO seeded $Y_{1.8}Ba_{2.4}Cu_{3.4}O_y$/Ag melt-texturing process" *Physica C* **357-360**, 734-737 (2001)

C. Cai, M. Tachiki, T.. Jujii, T. Kobayashi, H.K. Liu and S.X. Dou, "Optimized $NdBa_2Cu_3O_y$ thin films deposited by eclipsed pulsed laser ablation", *Physica C* **356**, 205-211 (2001).

W.M. Chen, Y.C. Guo, X.K. Fu, H.K. Liu, S.X. Dou and M. Apperley, "Comparative studies on "sandwich" rolling and flat rolling in processing Ag/Bi-2223 tapes"*IEEE Trans. Appl. Supercond.* **11, 1**, 3752-3755 (2001)

W.M. Chen, Y.C. Guo, G. McCaughey, M. Apperley, H.K. Liu and S.X. Dou, "Effect of various mechanical deformation techniques on critical current densities of Ag/Bi-2223 tapes" *Physica C*, **354**, 349-352 (2001)

W.M. Chen, F. Wang, S.S. Jiang, H.K. Liu and S.X. Dou "Upper critical field H_{c2} on *c* axis of Ag/Bi-2223 polycrystal tape" *J. Supercon.* **14, 4**, 463-466 (2001)

W.M. Chen, D.Q. Shi, X.K. Fu, H.K. Liu, T. Silver and S.X. Dou "Effect of various intermediate deformation techniques on J_{vc} and grain texture for Ab/Bi-2223 tapes" *J. Supercon.* **14, 4**, 537-541 (2001)

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H.T. Cooper, W. Gao, S. Li, H.K. Liu and S.X. Dou, "Intrinsic deformation behaviour in pressed Bi-Sr-Ca-Cu-O Tapes" *Supercond. Sci and Tech.*, **14**, 862-869 (2001)

S.X. Dou, X.L. Wang, J. Horvat, D. Milliken, A.H. Li, K. Konstantinov, E.W. Collings, M.D. Sumption and H.K. Liu "Flux jumping and a bulk-to-granular transition in the magnetization of a compacted and sintered MgB_2 superconductor" *Physica C* **361**, 79-83 (2001)

X.K. Fu, Y.C. Guo, W.M. Chen, H.K. Liu and S.X. Dou "Effect of the sinter-forging deformation rate on properties of Bi-2223 current leads" *IEEE Trans. Appl. Supercond.* **11, 1**, 2551-2554 (2001)

F. Gao, R.A. Lewis, X.L. Wang and S.X. Dou, "Phonon Modes of $A(Co_{1/2})O_3$(A = La, Nd, Dy, Ho, Yb)" *J. Solid State Chemistry* **160**, 350-352 (2001)

F. Gao, X.L. Wang, R.A. Lewis, P. Mikheenko, S.X. Dou "Synthesis and magnetic properties of perovskite $La_{1-x}Ca_xMn_{0.9}Li_{0.1}O_3$" *J. Alloys & Compounds* **325**, 281-284 (2001)

Y.C. Guo, W.M. Chen, H.K. Liu, S.X. Dou and A. V. Lukashenko, "Improved uniformity of microstructure and electrical properties of Bi-2223/Ag superconducting tapes" *Physica C,* **355**, 163-171 (2001)

J. Horvat, "Grain connectivity and vortex pinning in high-temperature superconductors" *Handbook Adv. Elec. and Photonic Mat. and Devices – High Tc Superconductors and Organic Conductors,* Edit: H.S. Nalwa, **3, Chap. 3,** 129-168 (2001)

A. Li, X.L. Wang, M. Ionescu, S. Soltanian, J. Horvat, T. Silver, H.K. Liu and S.X. Dou "Fast formation and superconductivity of MgB_2 thick films grown on stainless steel substrate" *Physica C* **361**, 73-78 (2001)

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H.K. Liu, A. Polyanskii, W.M. Chen, Y.C. Guo, S.X. Dou * M. Apperley, "Magneto-optical images of Ag/Bi-2223 tapes processed by flat rolling, "sandwich" rolling and pressing" *IEEE Trans. Appl. Supercond.* **11, 1**, 3764-3767 (2001)

A.S. Mahmoud, G.J. Russell, M.R. Koblischka, N. Chikumoto, M. Murakami, J. Horvat and S.X. Dou, "Scaling of the magnetic response and field dependence for the characteristic pinning energy in $(Y,Nd)Ba_2Cu_3O_\delta$" *Supercond. Sci and Tech.*, **14**, 311-314 (2001)

D. Marinaro, S.X. Dou, J. Horvat, J. Boldeman, R. Weinstein and R. Sawh, "Effect of uranium doping and thermal neutron irradiation on the flux-pinning of silver-clad Bi-Sr-Ca-Cu-O tapes,, *IEEE Trans. Appl. Supercond.* **11, 1**, 3896-3899 (2001)

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D. Milliken, J.H. Ahn and S.X. Dou, "Phase formation and thermal treatment optimisation in uranium compound doped $(Bi,Pb)_2Sr_2Ca_2Cu_3O_x$/silver superconducting tapes" *Physica C,* **354**, 183-188 (2001)

V.M. Pan and A.V. Pan, "Vortex matter in superconductors" *Low Temp. Physics*, **27, 9-10**, 732-746 (2001)

M.J. Qin, X.L. Wang, S. Soltanian, A.H. Li, H.K. Liu and S.X. Dou "Dependence of the flux-creep activation energy on current density and magnetic field for the MgB_2 superconductor" *Physical Rev. B* **64**, **6** 060505 (R) 1-4 (2001)

D.Shi, M. Ionescu. J. McKinnon and S.X. Dou, "Growth orientation and surface morphology of CeO_2 films deposited by PLD using different deposition atmospheres" *Physica C* **356**, 304-310 (2001)

S. Soltanian, X.L. Wang, I. Kusevic, E. Babic, A.H. Li, M.J. Qin, J. Horvat, H.K. Liu, E.W. Collngs, E. Lee, M.D. Sumption and S.X. Dou "High-transport critical current density above 30K in pure Fe-clad MgB_2 tape" *Physica C,* **361**, 84-90 (2001)

S. Soltanian, X.L. Wang, H.K. Liu, J. Horvat, T. Silver and S.X. Dou, "Effects of Cr doping on the structure, charge ordering, transport and spin ordering state in $Nd_{0.5}Sr_{0.5}Mn_{1-x}Cr_xO_3$" *Physica C* **364-365** 343-346 (2001)

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S. Tönies, H.W. Weber, Y.C. Guo, S.X. Dou, R. Sawh and R. Weinstein, "Improved in-field behaviour of uranium doped BiSCCO tapes by enhanced flux pinning" *IEEE Trans. Appl. Supercond.* **11, 1**, 3904-3907 (2001)

S. Tönies, H.W. Weber, Y.C. Guo, S.X. Dou, R. Sawh and R. Weinstein, "On the current transport limitations in Bi-based high temperature superconducting tapes" *App. Phys. Lett.* **78, 24**, 3851-3853 (2001)

K.K. Uprety, J. Horvat, X.L. Wang, M. Ionescu, H.K. Liu and S.X. Dou, "Enhancement of vortex pinning by Josephson coupling of two-dimensional pancake vortices in heavy lead-doped $Bi_{2-\chi}Pb_{\chi}Sr_2CaCu_2O_y$" *Supercond. Sci. and Tech.*, **14**, 479-485 (2001)

X.L. Wang, J. Horvat, H.K. Liu, A.H. Li and S.X. Dou, "Spin glass state in Gd_2CoMnO_6 perovskite manganite" *Sol. State Commun.,* **118**, 27-30 (2001)

X.L. Wang, H.K. Liu and S.X. Dou, "Segregation growth of $Bi_2(Sr,Ca)_2CuO_y$ single crystals by using self-fluxes", *J. Mat. Sci. Lett*, **20**, 1455-1457 (2001)

X.L. Wang, H.K. Liu and S.X. Dou, "Study of the peak effect in pure, Pb and Pb + Y doped Bi-2212 single crystals" *Physica C* **364-365**, 622-625 (2001)

X.L. Wang, H.K. Liu, S.X. Dou, J. Horvat, D. Milliken, G. Heine, W. Lang, H.M. Luo and S.Y. Ding, "Superconductivity and flux pinning in Y and heavily Pb codoped Bi-2212 single crystals" *J. of App. Physics*, **89, 11B,** 7699-7671 (2001)

X.L. Wang, S. Sontanian, J. Horvat, A.H. Li, M.J. Qin, H.K. Liu and S.X. Dou, "Very fast formation of superconducting MgB_2/Fe wires with high J_c" *Physica C* **361**, 149-155 (2001)

Y.B. Zhang, S. Li, C.Q. Sun, W. Gao, S.X. Dou and P. Hing, "Observation of heat flow at transition temperature in $La_{1-x}Ca_xMnO_{3+\delta}$ Oxides" *J. App. Physics* **90, 9**, 4583-4586 (2001).

Y.B. Zhang, S. Li, P. Hing, C.Q. Sun, W. Gao and S.X. Dou, "Thermal transition behaviour of $La_{1-x}Ca_xMnO_{3-\delta}$ oxides" *Solid State Commun.**120**, 107-112 (2001)*

Battery Program

J.H. Ahn, G.X. Wang, H.K. Liu and S.X. Dou "Mechanically milled nanocrystalline Ni_3Sn_4 and $FeSi_2$ alloys as an anode material for Li-ion batteries" *Materials Science Forum* **360-362**, 595-602 (2001)

J. Wang, S. Zhong, G.X. Wang, D.H. Bradhurst, M. Ionescu, H.K. Liu and S.X. Dou, "Electrochemical performance of nanocrystalline lead oxide in VRLA batteries" *J. Alloys & Compounds* **327**, 141-145 (2001)

G.X. Wang, J.H. Ahn, M.J. Lindsay, L. Sun, D.H. Bradhurst, S.X. Dou and H.K. Liu "Graphite-Tin composites as anode materials for lithium-ion batteries" *J. Power Sources* **97-98**, 211-215 (2001)

G.X. Wang, M.J. Lindsay, M. Ionescu, D.H. Bradhurst, S.X. Dou and H.K. Liu "Physical and electrochemical characterisation of $LiNi_{0.8}Co_{0.2}O_2$ thin-film electrodes deposited by laser ablation" *J. Power Sources* **97-98**, 298-302 (2001)

Solid State Physics Program

R.L. Causley and R.A. Lewis, "Far-infrared spectroscopy of the zinc acceptor in indium phosphide" *Physica B* **302-303**, 327-333 (2001)

P. Fisher, B.D. Crowe, R.E.M. Vickers and A.B. Rosenfeld "Impurity spectra in germanium due to bulk stress from surface strain" *Physica B* **302-303**, 317-326 (2001)

P. Fisher and R.E.M. Vickers "Bulk stress due to surface damage of crystalline silicon and germanium" *App. Phy. Lett.* **79, 21** 3458-3460 (2001)

R.A. Lewis "Phonon modes in CMR manganites at elevated temperatures" *J. of Supercond.***14, 1**, 143-148 (2001).

B.C. Lough, S.P. Lee, R.A. Lewis and C. Zhang, "Electronic thermal transport and thermionic cooling in semiconductor multi-quantum-well structures" *Computer Phys. Communs.* **142**, 274-280 (2001)

B.C. Lough, S.P. Lee, R.A. Lewis and C. Zhang, "Numerical calculation of thermionic cooling efficiency in a double-barrier semiconductor heterostructure" *Physica E* **11**, 287-291 (2001)

W. Xu and C. Zhang "Dynamical Franz-Keldysh effect of an electron gas in high magnetic fields and intense laser fields" *Physica B* **298**, 339-343 (2001)

C. Zhang "Electronic states and dielectric response of an electron gas under a quantizing magnetic field and an intense laser" *Computer Phys. Communs.* **142**, 374-381 (2001)

C. Zhang "Resonant tunnelling and bistability in a double barrier structure under an intense terahertz laser" *App. Physics Lett.* **78, 26,** 4187-4189 (2001)

C. Zhang and W. Xu, "Electronic states and dielectric response of a two-dimensional electron gas in a strong magnetic field and an intense laser field" *Physica B* **298,** 333-338 (2001)

Funding 2001

Australian Research Council Grants

ARC Large Scheme Grants

S.X. Dou	Enhancement of transport Jc in magnetic field of Ag/BiPbSrCaCuO tapes by fission tracks	$71,945	
S.X. Dou	Growth mechanism & flux pinning in spiral grown HTS crystals	$62,488	
H.K. Liu	Cryogenic deformation and high T_c phase formation-partial decomposition of superconducting tapes	$62,000	
H.K. Liu	Current limiting mechanism in Ag sheathed (Bi,Pb)SrCaCuO tapes using magneto-optical imaging and magnetic force microscopy	$62,000	
H.K. Liu	Growth characterisation and flux pinning behaviourof doped TISrCa2Cu3Oy and TISr2CaCu2Oy high temperature superconducting single crystals	$59,954	**$318,387**

ARC Small Scheme Grants

M. Ionescu	Improvement of Surface Quality of Y-123 High Tc Superconducting Thin Film Produced by Pulsed Laser Deposition	$9,000	
K. Konstantinov	Preparation and characterization of advanced nano-crystalline oxide materials based on Australian mineral recourses for application in Li-ion batteries	$9,000	
R. Lewis	Optical study of organic semiconductors	$5,600	
X.L. Wang	Study of charge and spin ordering and colossal magnetoresistance in perovskite manganites	$9,000	**$32,600**

Indicative Near Miss Grant Allocations

D. Bradhurst, S. Zhong	The development and fundamental study of new lithium-ion battery systems	$10,000	
S.X. Dou, S. Zhong	An advanced battery charging technique and related apparatus for electric vehicles	$10,000	**$20,000**

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	$90,666	
W. Xu	Generation of coherent-hypersound from semiconductor systems	$72,276	
Y.C. Guo	APDA, Silver Alloy Sheathed HTS wires	60,000	**$222,942**
			$593,929

carried forward **$593,929**

ARC Strategic Partnerships with Industry – Research & Training (SPIRT)

S.X. Dou, T. Beales & E.W. Collings	Effective transverse resistivity of Bi-HTS tapes	$77,000	
S.X. Dou, M. Apperley	Investigation of Bi-2223/Ag superconductor winding for application In electrical fault current limiter	$98,000	
J. Horvat & M. Ionescu	Substrate for large area YBCO film depositon by laser ablation	$22,283	
H.K. Liu, D Bradhurst S. Zhong	High Energy Batteries for electric vehicles	$73,000	
H.K. Liu, M. Apperley RP Zhao, B. Zeimetz, T Chandra	Reduction of heat leak of high T_c superconducting current leads	$85,314	
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	$60,234	**$438,123**

ARC international Researcher Exchange Program (IREX)

S.X. Dou, E.H. Brandt	Electromagnetic behaviour of HTS in various geometries	$23,000	
S.X. Dou, JH Ahn	Preparation of nanocrystalline alloys by mechanically activated annealing	$87,178	
H.K. Liu, P. Majewski	Phase equilibrium diagram of Ag/Bi2O3-PbO-SrO-CaO-CuO system	$62,424	**$172,602**

ARC Research Infrastructure Equipment Facilities (RIEF)

S.X. Dou, R. Lewis, H.K. Liu, R. Ramer, J. Majierska, T. Beales	High Resolution Scanning Magnetic Microscope	$408,639	
	ARC funds	$240,000	**$648,639**
	Institution contributions		

Australian Institute of Nuclear Science & Engineering

P. Fisher	Compensation of boron-doped silicon by neutron transmutation doping with phosphorus	$13,950	
M. Ionescu	Implant of amorphous tracks in Bi-2212 thin films	$5,035	
R.A. Lewis	Colossal magnetoresistance films grown by laser ablation	$5,740	
D. Marinaro, S.X. Dou	Special Postgraduate Award	$6,550	
D. Bradhurst	In-situ structural studies of electrode materials for lithium ion batteries	$2,310	**$33,585**

$1,845,153

carried forward		**$1,845,153**
Industry Grants		
Metal Manufactures Ltd	$115,000	
Lexel Battery Co Ltd	$30,000	**$145,000**
Department of Education Training & Youth Affairs		
Scholarships		**$155,000**
University of Wollongong Support		
ISEM Performance Indicators	$145,900	
Faculty of Engineering funding	$25,000	
ISEM Management Fund	$75,000	
Director's costs	$141,000	
Postgraduate student maintenance funds	$18,000	
Scholarships	$135,000	**$539,900**
Total Funding for 2001		**$2,685,053**