

2010

# ANNUAL REPORT

**ISEM**  
WOLLONGONG



University of Wollongong



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# ISEM Postgraduate Student Awards



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

## 2010 POSTGRADUATE STUDENT EXCELLENCE AWARD RECIPIENT

Yi Du (photo 1)



2

## 2010 POSTGRADUATE STUDENT BEST THESIS AWARD RECIPIENT

Shulei Chou (photo 2)

## 2010 POSTGRADUATE STUDENT MERIT AWARD RECIPIENTS

Mohammad Ismail (photo 3)

Khay Wai See (photo 4)

Peng Liu (photo 5)



3

## 2010 POSTGRADUATE STUDENT BEST PAPER AWARD RECIPIENTS

Guodong Du (photo 6)

Yee Sin Ang (photo 7)



4

## 2010 CHINESE GOVERNMENT SCHOLARSHIP AWARDS

Yi Du (photo 8)

Guodong Du (photo 9)

Jianfeng Mao (photo 10)



5



6



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# Director's Report

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This year proved to be another memorable year for the Institute for Superconducting and Electronic Materials (ISEM) and for those associated with us. In the two years since ISEM moved into the Australian Institute for Innovative Materials (AIIM) Facility on the University's Innovation Campus we have experienced rapid growth in the number of research projects and directions, new partnerships with industry and other academic organisations and an influx of postgraduate students.

Throughout 2010 we continued to pursue our goal of having both ISEM and the University of Wollongong recognised among the best research institutions in the world. In August 2010 this commitment was rewarded with the University of Wollongong receiving a maximum five star rating for research intensity in the 2011 Good Universities Guide. Staff and students at ISEM have contributed strongly to building this strong research reputation publishing 156 publications with 2149 citations during 2010.

In addition to record high publication and citation levels, ISEM continues to attract strong financial support, securing almost \$4 million in research funding. We

have continued to excel in postgraduate enrolments and PhD completions with a record 58 students enrolled and 12 graduates. These achievements continue a strong track record of success and contributed to ISEM continuing its status as Research Strength of the University of Wollongong. I am confident that our success will continue in 2011 and beyond as ISEM remains an Australian flagship research institute.

The AIIM Facility provides the research infrastructure on which we will continue to build our success. This year we added to our already impressive stock of equipment purchasing a state-of-the-art single crystal growth facility, new x-ray diffraction equipment, TG/DTA system, as well as 15T and 9T magnets for the transport and characterisation of samples. We have also improved our EBE/XPS system through the National Cooperative Research Infrastructure Scheme. The expansion of the AIIM Facility will allow ISEM to further improve our research infrastructure with funds secured under the Education Investment Fund dedicated to purchasing high quality equipment, in particular for the world-class clean room laboratory that

has been specially designed to explore advanced manufacturing of microelectronic devices.

ISEM staff continue to dedicate themselves to continually improving our facilities spending considerable time commissioning new equipment and maintaining existing equipment.

The ongoing success of ISEM will be supported by the new \$43.8 million Australian Institute for Innovative Materials Processing and Devices (AIIM P&D) Facility, with ISEM being actively involved in design decisions so that this important facility meets the needs of our researchers and industry partners. The AIIM P&D Facility will continue to support ISEM's active engagement with industry, allowing us to develop the new processes and devices necessary to bridge the gap between fundamental research and commercialisation. Construction is well underway and our expanded laboratory and office space is expected to be available to us in the second half of 2011. The expanded AIIM Facility and the two flagship research institutes it houses – ISEM and the Intelligent Polymer Research Institute – will be of enormous benefit not only to the future

of the University but also to the broader Illawarra community and to Australia as our researchers set about tackling some of the world's biggest problems.

Our strength remains in the success of our researchers who continue to achieve important results across the broad spectrum of our research programs – superconductors, renewable energy materials, magnetic and ferroelectric materials, spintronics, terahertz science and nanotechnology.

We have secured an important US patent for the development of magnesium diboride superconductor wires, an innovation that places ISEM among the top research groups in the world in the field of superconductor applications. The multi-kilometre technical conductor wires have been produced by our industry partner Hyper Tech Research Inc. using our patented technology of carbohydrate doped  $\text{MgB}_2$ . In addition, in collaboration with Zenergy Power, the design and modeling of an innovative industry scale fault current limiter is well advanced.

In superconductor electronics, the effort made in Josephson junction and lithography patterning in collaboration with the CSIRO is an invaluable step for device applications.

In the newly discovered Fe-based superconductors, we found that  $(\text{Ba}, \text{K})\text{Fe}_2\text{As}_2$  single crystals become isotropic at low temperatures and high magnetic fields, resulting in a very rigid vortex lattice, even in fields very close to  $H_{c2}$ . The  $(\text{Ba}, \text{K})\text{Fe}_2\text{As}_2$  crystal has shown the highest pinning potential among all new superconductors.

Advancing battery technologies to develop a low cost, high power rechargeable battery continues to be a focus of our research program. We have developed a number of nano-composites and three-dimensional materials for electrodes in lithium ion batteries showing high rates of charge and discharge at a current density of  $10^\circ\text{C}$  for more than 1000 cycles without compromising the energy capacity. This development will have considerable impact on the future of electric vehicle and hybrid electric vehicle power sources.

Graphene based composites developed for supercapacitors show considerable potential for large scale applications and a provisional patent has been filed for IP protection.

We were also successful in our research on hydrogen storage materials such as magnesium borohydrate which has shown

up to 7.2 et % hydrogen storage capacity at  $160^\circ\text{C}$  – comparable to the pure  $\text{Mg}(\text{BH}_4)_2$  at  $300^\circ\text{C}$ .

For multiferroic materials, we have reported electromagnetic properties of novel Bi based material. While in the field of terahertz electronics, we have discovered several new materials and systems which have strong terahertz emission. For example, nanoporous honeycomb membranes on  $\text{InP}$  (111) surfaces emit ultrafast coherent terahertz pulses under near-infrared optical excitation. We have identified a number of graphene nanostructures such as nanoribbons and nano-domains which exhibit very strong nonlinear optical response in terahertz regime. Also time-domain spectroscopy experiments are continuing to reveal the role played by various physical mechanisms in generating terahertz-frequency electromagnetic radiation. A new and unusual line of investigation is in exploring the emission of radiation - both terahertz and x-ray - from peeling adhesive tape.

I would like to congratulate and recognise the promotion of several staff this year. Dr Zaiping Guo was promoted to Associate Professor, Dr Jiazhao Wang and Dr Zhenxiang Cheng to Senior Principal Researchers and Dr Yue Zhao to Senior

Lecturer while Associate Professor Guoxiu Wang relocated to the University of Technology, Sydney and we wish him well in his future endeavours.

Other staff members whose achievements deserve to be acknowledged include our PhD student Khay Wai See who successfully established a very efficient measurement system for the characterisation of superconducting wires and coils, Darren Attard who was critical to the restoration of our electron beam lithography system and PhD students Yi Du and Nanda Masilamani who have explored the MFM capability of AFM and EBL of SEM respectively.

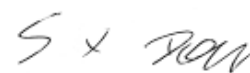
Our postgraduate students worked hard on their projects and have achieved many significant results with the best achievers receiving ISEM's annual Excellence, Merit and Best Paper Awards and the Postgraduate Student Best Thesis Award. Three PhD candidates were awarded prestigious Chinese Government Scholarship Awards honouring the academic excellence of self-financed Chinese students studying overseas. I look forward to welcoming our new students and believe that the achievements of our

past and current students will motivate them to achieve even greater results in their scientific journeys.

ISEM continues to attract many national and international visitors to present their latest research findings and exchange ideas and develop collaborative arrangements. Visitors this year included Professor E.W. Collings from Ohio State University, Professor E. Brandy from the Max Planck Institute in Germany, Dr K. Ozawa of the National Institute for Materials Science in Japan, Professor M. Das from the Australian National University and others who visited to give outstanding presentations and share their knowledge with students and staff. We are grateful to these researchers for being generous with their time and for their willingness to share their knowledge and experiences.

Continued investment in high quality research equipment, strong support for staff and the provision of outstanding supervision and support for postgraduate students and early career researchers are the hallmark of our success and are important to ISEM's future growth the maintenance of its reputation as a world-class research institute. I am confident that ISEM's unique

combination of high quality facilities, world-class researchers and a commitment to developing new and innovative ways to address some of the most challenging of problems will drive further ground breaking research in the years ahead.



Prof. Shi Xue Dou PhD, DSc, FTSE

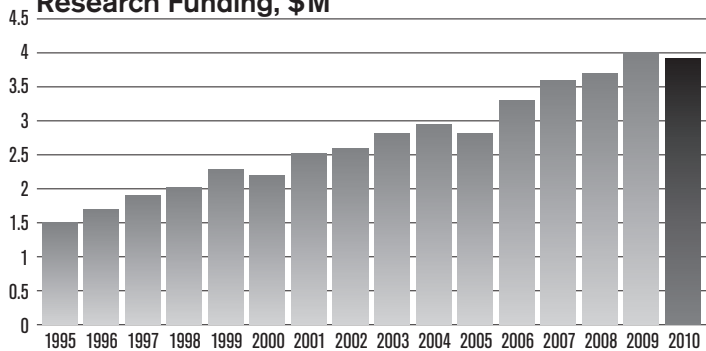
Director

ARC Australian Professorial Fellow

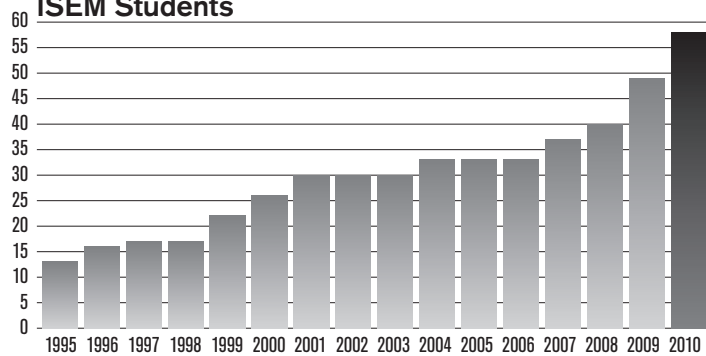


# ISEM at a Glance

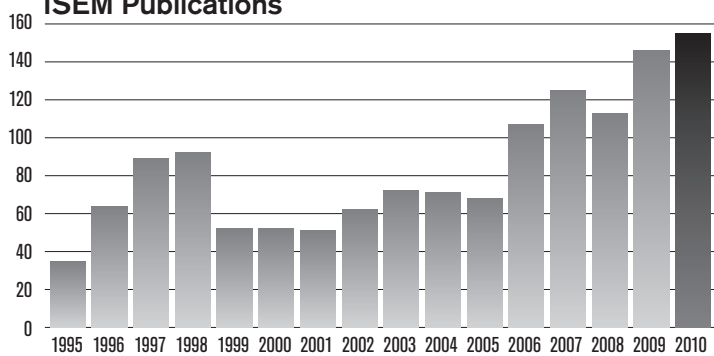
## Research Funding, \$M



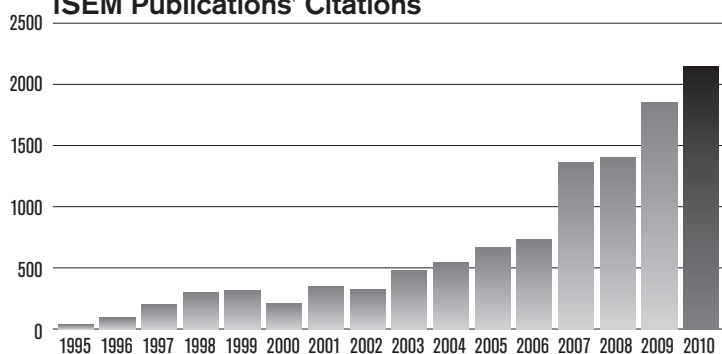
## ISEM Students



## ISEM Publications



## ISEM Publications' Citations



# Management

## Management Committee

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

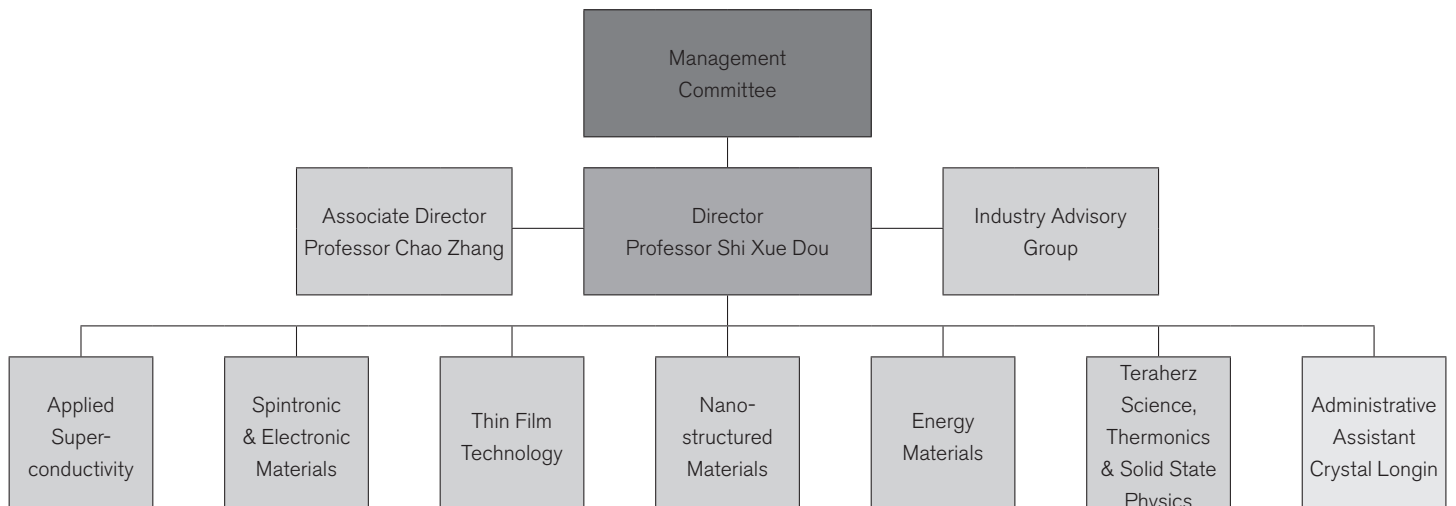
## Industry Advisory Group

Dr. F. Darmann	Managing Director, Zenergy Power Ltd.
Mr. J. F. Wu	Marketing Manager, DLG Battery Co Ltd, Shenzhen, P. R. China
Mr. M. Tomsic	Managing Director, Hyper Tech Research Ltd, Ohio, USA,
Dr. X. F. Gao	General Manager, Lexel Batteries Co. Ltd, Shenzhen, P. R. China
Dr. S. Cooper	Chief Technological Officer, Mesaplexx Ltd, Brisbane, QLD, Australia
Mr. A. Kittel	Managing Director, Redarc Electronics, Adelaide, SA, Australia
Mr. R. Blade	Director, Blade Electric Vehicles Pty Ltd, QLD, Australia
Mr. J. Brown	Managing Director, ChargePoint Australia, NSW, Australia
Dr. Y. Sharma	Chief Technological Officer, Galaxy Resources Ltd
Mr. J. Y. Xu	Chief Executive Officer, Ningbo Jain Sen Mechanism Ltd

## Advisory Committee

Prof. R. Taylor	Adjunct Professor, Queensland University of Technology, Australia
Dr. O. Mukhanov	Chief Technological Officer, Hypres Ltd, USA
Prof. P. Robinson	Chair, Cast CRC Ltd

## Organisational Chart



# Personnel

## DIRECTOR

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

## ASSOCIATE DIRECTOR

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

## SENIOR PROGRAM COORDINATORS

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

- ▶ Prof. Xiaolin Wang (BSc, MSc, PhD, ARC QE-II Fellow)
- ▶ Prof. Chao Zhang (BSc, PhD, MA, MPhil, FAIP)

## ARC FELLOWS

- ▶ Prof. Hua Kun Liu (Dipl. For PGS, Dipl. AQC, ARC Australian Professorial Fellow)
- ▶ A/Prof. Alexey Pan (BSc, MSc, PhD, ARC Australian Research Fellow)
- ▶ A/Prof. Guoxiu Wang (BSc, MSc, PhD, ARC QE-II Fellow)
- ▶ A/Prof. Zaiping Guo (BSc, MSc, PhD, ARC QE-II Fellow)
- ▶ Dr. Jungho Kim (BSc, MSc, PhD, ARC Postdoctoral Fellow)

- ▶ Dr. Xuebin Yu (BSc, MSc, PhD, ARC Postdoctoral Fellow)
- ▶ Dr. Dapeng Chen (BSc, MSc, PhD, ARC Postdoctoral Fellow)
- ▶ Dr. Germanas Peleckis (BCh, MSc, PhD, ARC Postdoctoral Fellow)
- ▶ A/Prof. Zhenxiang Cheng (BSc, MSc, PhD, ARC Future Fellow)
- ▶ Dr. Xun Xu (BSc, MSc, PhD, ARC Postdoctoral Fellow)
- ▶ Dr. Ziqi Sun (BSc, MSc, PhD, ARC Postdoctoral Fellow)
- ▶ Prof. Tom Johansen (ARC International Fellow)
- ▶ Prof. G. Hong (ARC International Fellow)



**RESEARCH STAFF**

- ▶ Dr. Feng Gao (BSc, PhD)
- ▶ Dr. Tania Silver (BSc, PhD)
- ▶ Dr. Rong Zeng (BSc, MSc, PhD)
- ▶ Dr. Olga Shcherbakova (PhD)
- ▶ Prof. Xiaoping Shen
- ▶ Dr. Dongqi Shi (BSc, MSc, PhD)
- ▶ Dr. Ivan Nevirkovets (NCRIS Fellow)
- ▶ Dr. Jiazhao Wang (BSc, MSc, PhD)
- ▶ Dr. Chun Chang Wang
- ▶ Dr. Yueping Yao
- ▶ Dr. Sima Aminorroaya
- ▶ Dr. Yun Zhang
- ▶ Dr. Sihai Zhou (BSc, MSc, PhD)

**FACULTY STAFF**

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

**SENIOR LECTURER**

- ▶ Dr. Yue Zhao (MSc, PhD)

**VISITING STAFF**

- ▶ Dr. Shi Zhong (Delong Energy Technology, China)
- ▶ Dr. Gustavo Alvarez
- ▶ Dr. Hai Bo Lu
- ▶ Dr. Jieqiang Wang

- ▶ Dr. Xianlong Wang
- ▶ Dr. Xibin Xu
- ▶ Dr. Yunlong Xu
- ▶ Dr. Zunxian Yang
- ▶ Dr. Qinghua Chen
- ▶ Dr. Zuyong Feng
- ▶ Dr. Xianjun Zhu

**TECHNICAL STAFF**

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

**ADMINISTRATION ASSISTANT**

- ▶ Ms. Crystal Longin

**HONORARY FELLOWS**

- ▶ Dr. Scott Needham
- ▶ Prof. Edward Collings (Ohio State University)
- ▶ Prof. Shane Kennedy
- ▶ Prof. Tom Johansen

# Postgraduate Students

## Current

PhD	Thesis Title	Supervisors
Mr. Seyed Hamed Aboutalebi	Nanoceramics for Supercapacitor Applications	Dr. Kosta Konstantinov
Mr. Dieter Beaven	FPGA architecture for numerical computations	Prof. John Fulcher, Prof. Chao Zhang
Mrs. Fargol Bijarbooneh	Nanowires in arrays based nanostructures	Dr. Yue Zhao, Dr. Jung Ho Kim
Mr. Colin Bleasdale	Electromagnetic properties of superconducting films and multilayers	Prof. Chao Zhang, A/Prof. Alexey Pan
Mr. Alfred Chidembo	Advanced Nanoceramics and Composites for Supercapacitors	Dr. Kosta Konstantinov, Prof. Hua Kun Liu
Mrs. Kaludewa Sujeewa De Silva	Improving superconducting Properties of MgB <sub>2</sub> by chemical doping using graphene as C source	Dr. Xun Xu, Prof. Xiaolin Wang, Prof. Shi Xue Dou
Mr. Jyotish Debnath	Nanostructure control of MgB <sub>2</sub> by chemical doping	Prof. Shi Xue Dou, Dr. Jung Ho Kim, Dr. Rong Zeng
Mr. Guodong Du	Performance improvement of cathode materials for Li-ion battery	Dr. Zaiping Guo, Prof. Hua Kun Liu
Mr. Yi Du	Diluted magnetic semiconductors (DMS's)	Prof. Xiaolin Wang, Dr. Zhenxiang Cheng
Mr. Muhamad Faiz	Nanomaterials for Biosensor.	Dr. Jianli Wang, Prof. Shi Xue Dou
Mr. Sergy Fedoseev	Investigation of Superconducting Thin Films and Multilayered Structures for Electronic Applications	A/Prof. Alexey Pan, Prof. Shi Xue Dou
Miss. Liya Feng	Spintronics	Prof. Xiaolin Wang, Dr. Zhenxiang Cheng
Miss. Xuanwen Gao	Development of Inorganic-conducting Polymer Composites and Ionic Liquid-based Electrolytes for Rechargeable Lithium Batteries	Prof. Hua Kun Liu, Dr. Jiazhao Wang
Mr. Igor Golovchanskiy	REBCO Superconducting Thin Films and Multilayers for Electronic Applications	A/Prof. Alexey Pan, Prof. Shi Xue Dou
Mr. Mohd Faiz Hassan	Nanostructured materials for lithium ion battery	Prof. Hua Kun Liu, Dr. Zaiping Guo
Mr Stuart Hargreaves	High Efficiency Terahertz Emitters	Roger Lewis
Mr. Eoin Hodge	Design, Build and Test of FCL Using MgB <sub>2</sub> Coils	Prof. Shi Xue Dou, A/Prof. Josip Horvat, Dr. Frank Darmann
Mr. Fang Hong	Spin Manipulation by Electrical Field	Prof. Xiaolin Wang, Dr. Zhenxiang Cheng
Mrs. Nurul Idris	Nanomaterials for lithium rechargeable batteries	Prof. Hua Kun Liu, Dr. Jiazhao Wang
Mr. Mohammad Ismail	Hydrogen storage materials	Prof. Shi Xue Dou, Dr. Yue Zhao, Dr. Xuebin Yu
Mr. Abolfazl Jalalian	Lead free Piezoelectric materials	Prof. Xiaolin Wang, Prof. Shi Xue Dou
Ms. Priyanka Jood	Oxide thermoelectric materials for high temperature power generation	Dr. Germanas Peleckis, Prof. Xiaolin Wang
Mr. Tomas Katkus	Superconducting and electro-magnetic properties of FeAs based superconductors	Prof. Xiaolin Wang, Dr. Germanas Peleckis
Mr. JaeGeun Kim	Research on Superconductor Thin Films	Prof. Shi Xue Dou, Dr. Dongqi Shi
Mr. Philip Lavers	Electronic structure of perovskite and related materials	Prof. Shi Xue Dou
Miss. Sha Li	Bio-compatible Materials for Batteries	A/Prof. Zaiping Guo, Prof. Gordon Wallace, Prof. Hua Kun Liu
Mr. Qi Li	Research on superconducting films and buffer layers for electronic applications	Prof. Shi Xue Dou, Dr. Dongqi Shi

PhD	Thesis Title	Supervisors
Mr. Hao Liu	Nanostructured materials for lithium ion batteries	Dr. Guoxiu Wang, Prof. Chao Zhang
Mrs Lin Lu	Electrolytes for rechargeable batteries	Dr. Jia Zhao Wang, Prof. Hua Kun Liu
Mr. Minoru Maeda	Critical current of MgB <sub>2</sub>	Prof. Shi Xue Dou, Dr Yue Zhao
Mr. Victor Malgras	Nanostructured TiO <sub>2</sub> for DSSC	Dr. Jung Ho Kim, Prof. Shi Xue Dou
Mr. Jianfeng Mao	Study on hydrogen storage behaviour of LiBH <sub>4</sub>	Dr. Zaiping Guo, Prof. Hua Kun Liu
Mr. Nandhagopal Masilamani	Josephson junctions and other electronic devices based on graphene	Dr. Ivan Nevirkovets, A/Prof. Alexey Pan, Prof. Shi Xue Dou
Mr. Mislav Mustapic	Enhancement of MgB <sub>2</sub> superconductor by magnetic nanoparticle doping	A/Prof. J. Horvat, Prof. Shi Xue Dou
Mr Lukman Noerochim	Improving the Capacity and Safety of Lithium Ion Battery	Prof Hua Liu, Dr Jiazhao Wang
Mr Jinsoo Park	Nanostructured Semiconducting Metal Oxides for use in Gas Sensors	A/Prof Guoxiu Wang, Prof Hua Liu
Mr Chung Kiak Poh	Metallic nanostructures, ultrathin films and optical technologies for hydrogen storage and switchable mirrors	A/PR Zaiping Guo, Prof Hua Liu
Mr MD Mokhlesur Rahman	Nanostructured Active Materials for Lithium-ion Batteries	Prof Hua Liu, Dr Jiazhao Wang
Mrs Maryam Salari	Application of Nanostructural Titania in Super Capacitors	Dr Konstantin Konstantinov, Prof Hua Liu
Mr Khaywai See	Superconductor Applications in Electrical Engineering	Prof Chris Cook, Prof Shi Xue Dou
Mr KuokHau Seng	Advanced Nanomaterials for Lithium Ion Batteries	A/PR Zaiping Guo
Mrs Mahboobeh Shahbazi	Study on Newly Discovered Fe-based Superconductors	Prof Shi Xue Dou, Prof Xiaolin Wang
Ms Precious Shamba	Novel Magnetocaloric Materials for Room Temperature Magnetic Refrigeration	Prof Shi Xue Dou, Dr Rong Zeng
Mr Andrey Shcherbakov	Magnesium Diboride Superconductor: thermal stabilization and doping	Prof Shi Xue Dou, A/PR Josip Horvat
Ms Yi Shi	Development of Materials for Room Temperature Sulfur Batteries	Dr Jiazhao Wang, Prof Hua Liu
Miss Lin Wang	Chemical solution deposition for YBCO superconducting films and Sm <sub>2</sub> O <sub>3</sub> buffer layers on single crystal and biaxially textured metallic substrates	Prof Shi Xue Dou, Dr Dongqi Shi
Mr Brad Winton	Low energy metal ion implantation of Poly-di-methylsiloxane (PDMS) for increased biocompatibility for use in tissue engineering applications	Prof Shi Xue Dou
Ms Huimin Wu	New Catalyst Materials for Hydrogen Fed Fuel-Cells.	Dr David Wexler, Prof Hua Liu
Mr Chaofeng Zhang	Three-Dimensional Nano-materials for Lithium-Ion Batteries	A/PR Zaiping Guo
Mr Peng Zhang	Synthesis and Characterization of Nanostructured Electrodes for Lithium-ion Batteries	Dr Zaiping Guo, Prof Hua Liu
Mr Chao Zhong	Composites and Ionic Liquid-based Electrolytes for Rechargeable Lithium Batteries	Dr Jiazhao Wang, Prof Hua Liu

Masters	Thesis Title	Supervisors
Ms. Azrin Chowdhury	Synthesis of Nanoceramics for Supercapacitors	Dr. David Wexler, Dr. Kosta Konstantinov
Mr. Rhys Hargreaves	Ultrafast Change of Magnetization as Terahertz Source	Prof. Roger Lewis, A/Prof. Josip Horvat
Mr. Peng Liu	Doping Effects on the Crystal Structural, Magnetic, and Dielectric Properties of the Multiferroic Hexagonal RMnO <sub>3</sub> (R=Er and Ho)	Prof. Xiaolin Wang, Dr. Zhenxiang Cheng

Mrs. Ruoqi Liu		
Mrs. Irin Sultana	Biodegradable Materials for Bio-Battery	Prof. Gordon Wallace, Prof. Hua Kun Liu, Dr. Jiazhao Wang
Mr. Bei Wang	Nanostructured materials for advanced supercapacitors	Dr. Guoxiu Wang
Mr. Zhenwei Yu	Thermoelectric Materials	Prof. Chao Zhang, Prof. Xiaolin Wang

## Completions

Name	Thesis Title	Awarded	Position	Appointed
S. L. Chou	Nanostructured / composite materials for rechargeable Li-ion battery and supercapacitor	2010	ARC Postdoctoral Fellow ISEM, University of Wollongong	2010
W.X. Li	Carbohydrate doping effect on the superconductivities and microstructure of MgB <sub>2</sub> superconductor	2010	ISEM, University of Wollongong	2010
S. Pysarenko	HTS multi-layers thin films fabrication	2010		
R. Nigam	Study of magnetic behaviour of Ru-based superconducting ferromagnets	2010	Research Associate, ISEM, University of Wollongong	2010
A. Ranjbar	Effect of catalysts on hydrogen storage properties of MgH <sub>2</sub>	2010	Research Associate, ISEM, University of Wollongong	2010
Q. Yao	Study of newly discovered two dimensional cobalt based perovskite compounds doped with various rare earth elements	2009	Research Associate, ISEM, University of Wollongong	2009
Y. Zhang	Improvement of critical current density in MgB <sub>2</sub> by optimizing process parameters and chemical doping	2009	Research Associate, ISEM, University of Wollongong	2009
X. Xu	Effect of starting boron powder on the superconducting properties of MgB <sub>2</sub>	2009	ARC APDI Fellow, ISEM, University of Wollongong	2010
S. Y. Chew	Advanced materials for electrodes and electrolyte in rechargeable lithium ion batteries	2009		
D. P. Chen	Crystal growth, magnetism, transport and superconductivity of two dimensional sodium cobalt oxide single crystals	2009	ARC APD Fellow, ISEM, University of Wollongong	2009
M. M. Farhodi	Studies of structures, transport and magnetic properties of doped novel three dimensional perovskite compounds	2009		
Y. P. Yao	A study of electro materials for lithium-ion batteries	2008	Part Time Associate Fellow, ISEM, University of Wollongong	2008
Z. W. Zhao	The liquid-phase synthesis and electrochemical application of novel inorganic nanocomposites	2008	Innovation Management Department, Bayer Technology and Engineering Co., Ltd., Shanghai, China	2008
O. Shcherbakova	Development of MgB <sub>2-x</sub> C <sub>x</sub> superconductors and understanding their electromagnetic behaviour	2008	Part Time Associate Fellow, ISEM, University of Wollongong	2008
M. S. Park	Synthesis and characterization of nanostructured electrode materials for rechargeable lithium ion batteries	2008	Energy Group, Emerging Centre, Samsung Advanced Institute of Technology, South Korea	2008

Name	Thesis Title	Awarded	Position	Appointed
M. S. A. Hossain	Study of superconducting and electromagnetic properties of undoped and organic compound doped MgB <sub>2</sub> conductors	2008	Applied Superconductivity Group, University of Geneva, Switzerland	2008
S.H. Ng	Nanostructured materials for electrodes in lithium-ion batteries	2008	Post doctorate Fellow, Electrochemistry Laboratory, Paul Scherrer Institute, Switzerland	2008
			Technical Customer Support Manager, Asia Pacific, Changzhou Timcal Graphite Corp. Ltd, Shanghai, China	2009
Z. G. Huang	Effects of compositions and mechanical milling modes on hydrogen storage properties	2008	Research Fellow, Department of Materials Science and Engineering, OHIO State University, USA	2008
S. A. Needham	Development of advanced electrode materials for lithium-ion batteries	2007	Commercialization Manager, University of Wollongong	2007
			Commercialization Manager, Intven Ltd.	2009
G. Peleckis	Studies on diluted oxide magnetic semiconductors for spin electronic applications	2007	Research Fellow, ISEM, University of Wollongong	2007
			ARC APD Fellow, ISEM, University of Wollongong	2010
M. Roussel	Magneto-optical imaging in superconductors	2007	Director of the Capacity Building Department, BlueEnergy, Nicaragua	2008
L. Yuan	Investigation of anode materials for lithium-ion batteries	2007	CEO	2006
M. O'Dwyer	Solid-state refrigeration and power generation using semiconductor nanostructures	2007	Trading Analytics, Energy Australia	2007
Y. Chen	Investigation on advanced active materials for lithium-ion batteries	2006	General Manager, DLG Battery Shanghai CO.LTD	2006
S. Bewlay	Investigation on Li-Co-Ni system for lithium ion batteries	2006	Patent Officer, Canberra	2006
A. Li	A study of the fabrication and characterization of high temperature superconductor YBa <sub>2</sub> Cu <sub>3</sub> O <sub>7</sub> thin films	2006	Associate Research Fellow, ISEM, University of Wollongong	2006
S. H. Pilehood	Electronic properties of semiconductor nanostructures under intense terahertz radiation	2006		
W. K. Yeoh	Control of nanostructure for enhancing superconductor performance through chemical doping	2006	Research Fellow, Cambridge University, U.K.	2007
Y. Zhao	Fabrication and characterization of superconducting PLD MgB <sub>2</sub> thin films	2006	APD Fellow ISEM, University of Wollongong	2006
			Lecturer, University of Wollongong	2008
S. Keshavarzi	Investigation of vortex dynamics of (Tl,Pb)(Sr,Ba) <sub>2</sub> Ca <sub>2</sub> Cu <sub>3</sub> O <sub>y</sub> and an alternative method for determination of the lock-in angle in twinned superconductors	2005	Lecturer, Shahrekord University, Iran	2005
F. Gao	Studies on the synthesis, characterization and properties of colossal magnetoresistive (CMR) materials	2004	Research Fellow, ISEM, University of Wollongong	2004
M. Lindsay	Data analysis and anode materials for lithium ion batteries	2004	Postdoctoral Research Fellow, University of New South Wales	2004
			Research Staff, ANSTO	2006
B. Lough	Investigations into thermionic cooling for domestic refrigeration	2004	Quantitative Analyst, ABN AMRO, UK	2005

Name	Thesis Title	Awarded	Position	Appointed
D. Milliken	Uranium doping of silver sheathed bismuth-strontium-calcium-copper-oxide superconducting tapes for increased critical current density through enhanced flux pinning	2004	Knowledge Transfer Partnership Associate, University of Leeds and AVX Ltd	2005
S. Soltanian	Development of superconducting magnesium diboride conductors	2004	Pro-Vice Chancellor, Kurdistan University, Iran	2005
C. Wang	Cathodic materials for nickel-metal hydride batteries	2004	Research Fellow, IPRI, University of Wollongong	2004
S. H. Zhou	Processing and characterization of MgB <sub>2</sub> superconductors	2004	APD Fellow, ISEM, University of Wollongong	2005
Z. P. Guo	Investigation on cathode materials for lithium-ion batteries	2003	APD Fellow, ISEM, University of Wollongong Lecturer, University of Wollongong	2003 2007
J. McKinnon	The fundamental mechanisms involved in the production of thin films by Pulsed laser	2003	Teacher, New South Wales Education Department	2003
D. Marinaro	A study into the effects of fission-fragment damage on activation Energies in Ag/Bi2223 tapes	2003	Scientist, DSTO Melbourne	2003
D. Q. Shi	Buffer layers for YBCO superconducting films on single crystal YSZ substrates and cubic texture Ni substrates	2003	Research Fellow, Korean Electrical Technology Institute, Korea Research Fellow, ISEM, University of Wollongong APD Fellow, ISEM, University of Wollongong	2002 2004 2007
J. Wang	Development of a novel plate making processing technique for Manufacturing valve-regulated lead-acid batteries	2003	Research Fellow, IPRI, University of Wollongong APD Fellow, ISEM, University of Wollongong Research Fellow, ISEM	2003 2004 2007
R. Baker	Zeeman and piezo-spectroscopy of antimony and aluminium in germanium	2001	Professional Officer, University of Wollongong	2003
X. K. Fu	Fabrication and characterization of Bi-2223 current lead	2002	Research Fellow, Texas A&M University, USA Research Fellow, University of Waterloo, Canada	2002 2005
K. Uprety	Magnetic hysteresis and relaxation in Bi2212 single crystals doped with iron and lead	2002	Research Fellow, Argonne National Lab, USA	2002
F. Darmann	AC Loss in high temperature superconductor	2001	Chief Engineer, Zenergy Power Ltd.	2004
G. X. Wang	Investigation on electrode materials for lithium-ion batteries	2001	APD Fellow, ISEM, University of Wollongong ARC QEII Fellow, ISEM, University of Wollongong Associate Professor, ISEM, University of Wollongong	2001 2006
J. P. Chelliah	Optical spectroscopy of semiconductors	2000		
L. Sun	Amorphous and nanocrystalline hydrogen storage alloy materials for nickel-metal hydride batteries	2000	Research Associate, Hydro-Quebec Research Institute, Canada Research Fellow, University Sherbrooke, Canada	2000 2002
X. L. Wang	Spiral growth, flux pinning and peak effect in doped and pure Bi-2212 HTS single crystal	2000	Research Fellow, ISEM, University of Wollongong ARC APD Fellow, ISEM, University of Wollongong ARC QEII Fellow, ISEM, University of Wollongong Associate Professor Professor	2000 2002 2005 2006 2008
R. Zeng	Processing and characterization of Bi-2223/Ag superconducting tapes	2000	Research Fellow, ISEM, University of Wollongong	2000

Name	Thesis Title	Awarded	Position	Appointed
J. Chen	High energy storage material for rechargeable nickel-metal hydride batteries	1999	NEDO Fellow, Osaka National Research Institute Professor, Nankai University, China	1999 2003
T. Silver	Near band-edge optical properties of MBE GaAs and related layered structures	1999	Research Fellow, ISEM, University of Wollongong	2000
G. Takacs	Spectroscopy of the effect of strains and magnetic field on shallow acceptor levels in germanium	1999	Lab Manager, University of Wollongong	1999
N. Cui	Magnesium based hydrogen storage alloy anode materials for Ni-MH secondary batteries	1998	Research Fellow, Alberta University, Canada Electrochemist, Energizer Co, USA	1997 2000
R. J. Heron	Far-infrared studies of semiconductors in large magnetic fields	1998	Postdoctoral Fellow, SUNY, Buffalo, USA Research Fellow, Janis Research Company Inc., USA	1997 2000
M. Ionescu	Growth and characterization of Bi-2212 crystals and improvement of Bi-2212/Ag superconducting tapes	1998	Assistant Director, ISEM, University of Wollongong Senior Research Scientist, ANSTO	1997 2004
J. X. Jin	(Bi,Pb) <sub>2</sub> Sr <sub>2</sub> Ca <sub>2</sub> Cu <sub>3</sub> O <sub>10+x</sub> /Ag high T <sub>c</sub> superconductors and their applications in an electrical fault current limiter and an electronic high voltage generator	1998	Research Fellow, ISEM, University of Wollongong ARC, APD Fellow, ISEM, University of Wollongong Professor, University of Electronic Engineering	1997 2000 2003
M. Lerch	Optical & electrical studies of resonant tunnelling heterostructure	1998	Lecturer, School of Engineering Physics, University of Wollongong	2006
S. Stewart	Thermodynamic and dielectric properties in modulated two-dimensional electronic systems	1998	ARC APD Fellow Teacher Associate Professor	1998 1999 2002
W. G. Wang	Fabrication and improvement of silver sheathed (Bi,Pb) <sub>2</sub> Sr <sub>2</sub> Ca <sub>2</sub> Cu <sub>3</sub> O <sub>10</sub> tapes by powder-in-tube technique	1998	R&D Manager, Nordic Superconductor Tech. Denmark Associate Director, Ningbo Materials Institute, Chinese Academy	1997 2007
B. Zeimetz	High temperature superconducting tapes & current leads	1998	Research Fellow, Cambridge Univ., U.K.	1999
S. Zhong	Investigation on lead-calcium-tin-aluminium grid alloys for valve-regulated lead-acid batteries	1998	ARC Postdoctoral Fellow, ISEM, University of Wollongong CEO, Leadcel Dynamic Energy Ltd, P.R. China CEO, Guangzhou Delong Energy Tech Ltd.	1997 2002 2003
B. L. Luan	Investigations on Ti <sub>2</sub> Ni hydrogen storage alloy electrode for Rechargeable nickel-metal hydride batteries	1997	NRC Fellow, National Res. Council of Canada Group Leader, Shape Transfer Process Integrated Manufacturing Technologies Institute, NRC, Canada	1997 1999
N. Vo	Design and characterization of HTS coils	1997	Research Fellow, Los Alamos Nat. Lab, USA Research Staff, Intermagnetics General Co., USA	1999 1998
A. Warner	A spectroscopic study of acceptors in germanium	1997	Consultant, Computer Industry	1999
J. M. Xu	Phase formation and transformation in the R-Fe-T system (R=Nd, Gd, Tb, Dy, Er, Ho, T and Lu, T=Si, Ti & Zr	1997	Research Fellow, St. George Bank, Australia	1998
M. Yavus	Powder processing of Bi-Pb-Sr-Ca-Cu-O superconducting materials	1997	Ass. Professor, Texas A&M University, Texas USA Ass. Research Professor, Tohoku University, Sendai, Japan Ass. Professor, University of Waterloo, Canada	1997 2000 2004
Q. Y. Hu	Fabrication and enhancement of critical currents of silver sheathed Bi <sub>1</sub> Pb <sub>2</sub> Sr <sub>2</sub> Ca <sub>3</sub> Cu <sub>3</sub> O <sub>10</sub> tapes	1996	Research Fellow, Florida State University, USA Research Scientist, Argonne National Lab., USA Senior Engineer, Lucent, USA	1997 1999 2001
J. Yau	Ag/Bi-2223 tape processing and mechanical properties	1994	Assistant Professor, City Polytechnic University	2000

Name	Thesis Title	Awarded	Position	Appointed
J. A. Xia	Characterization of melt-texture of YBCO HTS	1994	Research Fellow, Solar Cell Ltd	1995
Y. C. Guo	Investigation of silver-clad (Bi,Pb) <sub>2</sub> Sr <sub>2</sub> Ca <sub>2</sub> Cu <sub>3</sub> O <sub>10-x</sub> superconducting tapes	1994	STA Fellow, National Research Institute Of Metals, Japan ARC Postdoctoral Fellow, ISEM, University of Wollongong Senior IT Specialist, ITS, University of Wollongong	1997 1998 2002
A. Bourdillion	Microstructure, phase characterization and texture processing of HTS	1992	Senior Engineer, Hewlett Packard, Singapore Hewlett Packard, USA	1993 2000
M. Apperley	The fabrication of high T <sub>c</sub> superconductor wire	1992	Chief Technologist, Australian Superconductors Business Development Manager, University of Sydney	1993 2004
S.H. Ng	Nanostructured materials for electrodes in lithium-ion batteries	2008	Post doctorate Fellow, Electrochemistry Laboratory, Paul Scherrer Institute, Switzerland Technical Customer Support Manager, Asia Pacific, Changzhou Timcal Graphite Corp. Ltd, Shanghai, China	2008 2009

## Masters Course Graduates

Name	Thesis Title	Awarded	Position	Appointed
C. Zhong	Advanced materials for lithium ion batteries	2010	PhD Candidate, ISEM, University of Wollongong	2010
L. Lu	Enhancement of connectivity and flux pinning in MgB <sub>2</sub> superconducting bulk and wires	2009	PhD Candidate, ISEM, University of Wollongong	2009
Y. S. Wu	Fabrication of in-situ MgB <sub>2</sub> thin films on Al <sub>2</sub> O <sub>3</sub> substrate using off-axis PLD technique	2007	PhD Candidate, ANU	2008
Z. J. Lao	New materials for supercapacitors	2006	Engineer, Sydney	2007
B. Winton	A study of the magnetoresistance effect in Bi-2212 for the purposes of utilisation in magnetic field sensors	2005	PhD Candidate, ISEM, University of Wollongong	2005
Q. Yao	MgB <sub>2</sub> thin films	2005	PhD Candidate, ISEM, University of Wollongong	2005
P. Lavers	The mobility of large anions in crystals with the fluorite Structure	2004	PhD Candidate, ISEM, University of Wollongong	2004
J. Yao	Carbon based anode materials for lithium-ion batteries	2004	PhD Candidate, ISEM, University of Wollongong	2004
Z. W. Zhao	Nano-oxides fabricated in-situ by spray pyrolysis technique as anode materials for lithium secondary batteries	2004	PhD Candidate, ISEM, University of Wollongong	2004
K. Ishida	Landau spectra of ZnH and neutral Zn in germanium	2004		
S. Lee	Multilayer thermionic cooling in GaAs-Al <sub>x</sub> Ga <sub>1-x</sub> As heterostructures	2003		
Z. Zhang	The comparative research on the Ag-alloy sheathed Bi-2223 tapes	2003	Senior Staff, China-URC Ltd, Shanghai. PR China	2003
A. Li	Fabrication and characterization of novel substrates and superconducting thick films	2002	PhD Candidate, ISEM, University of Wollongong	2002
M. Farhoudi	AC loss in Ag/Bi-2223 tape in AC field	2002	PhD Candidate, ISEM, University of Wollongong	2003
M. Ling	Mechanism of outgrowth in multifilament Bi-2223 tape	2001		
E. Sotirova	Investigation of colossal magnetoresistance materials	2001	Learning Centre Employee, Communications Assistant, Star CD Pty Ltd	2002

Name	Thesis Title	Awarded	Position	Appointed
K. Uprety	Vortex properties of Bi-HTS	1999	PhD Candidate, ISEM, University of Wollongong	2000
			Research Fellow, Argonne National Lab., USA	2003
J. Z. Wang	Investigations on anode materials for rechargeable lithium-ion batteries	1999	PhD Candidate, ISEM, University of Wollongong	2000
			Research Fellow, ISEM, University of Wollongong	2003
F. Chen	The influence of selenium on lead-calcium-tin-aluminium	1998	PhD Candidate, University of Sydney	1999
G. Yang	Effect of element substitution on superconductivity	1997	Research Fellow, University of Melbourne	2000
N. Zahir	A new method for production and study of electrical properties of carbon foam	1996	PhD Candidate, Queensland University	1997
J. X. Jin	(Bi,Pb) <sub>2</sub> Sr <sub>2</sub> Ca <sub>2</sub> Cu <sub>3</sub> O <sub>10+x</sub> /Ag high T <sub>c</sub> superconductors and their applications in an electrical fault current limiter and an electronic high voltage generator	1994	Research Fellow, ISEM, University of Wollongong	1997
			ARC, PDF, ISEM, University of Wollongong	2000



# National and International Links

## Australia

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

## International

### Austria

- ▶ Atomic Institute of Austrian Universities, Vienna
- ▶ L. Boltzmann Institute of Physics

### Canada

- ▶ 'Ecole Polytechnique de Montreal
- ▶ University of Alberta

### Croatia

- ▶ University of Zagreb

### Germany

- ▶ Max-Planck-Institut für Metalloforschung

### India

- ▶ National Physical Laboratory

### Japan

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

### New Zealand

- ▶ University of Auckland
- ▶ Industrial Research Lab

### Peoples Republic of China

- ▶ Beijing University of Science and Technology
- ▶ Harbin University
- ▶ Hubei University
- ▶ Institute for Microsystems and Information Technology

- ▶ Institute of Electrical Technology

- ▶ Institute of Non-ferrous Metals

- ▶ Nankai University

- ▶ Nanjing University

- ▶ Northeastern University

- ▶ Shanghai Jiao Tong University

- ▶ Shanghai University

- ▶ Tianjin University

### Russia

- ▶ Institute of General Physics

### Singapore

- ▶ National University

- ▶ Nanyang University of Technology

### South Korea

- ▶ Andong National University

- ▶ Korea Advanced Institute of Science & Technology

- ▶ Korea Aerospace Research Institute (KARI)

- ▶ Korea Institute of Materials Science (KIMS)

- ▶ Korea Electrotechnology Research Institute (KERI)

### Switzerland

- ▶ University of Geneva

- ▶ Paul Scherrer Institute

### Ukraine

- ▶ Donetsk Physico-Technical Institute

- ▶ Institute for Metal Physics

### United Kingdom

- ▶ Imperial College

- ▶ Oxford University

- ▶ Southampton University

- ▶ University of Cambridge

### United States of America

- ▶ Ames Lab, Iowa State University

- ▶ Argonne National Laboratory

- ▶ Brookhaven National Laboratory

- ▶ Houston University

- ▶ Los Alamos Laboratory

- ▶ National Institute of Standard Technology

- ▶ New York Polytechnic University

- ▶ Ohio State University

- ▶ University of Wisconsin

- ▶ Rensselaer Polytechnic Institute

# Progress Reports for Projects Funded by the ARC

## ARC Centre of Excellence Research

### All solid-state lithium rechargeable batteries

(within the ARC Centre of Excellence for Electromaterials Science, Director: G. G. Wallace)

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

#### PROGRESS MADE IN 2010

Hollow-structured  $\alpha$ -Fe<sub>2</sub>O<sub>3</sub>/carbon (HIOC) nanocomposite with a high surface area of around 260 m<sup>2</sup>g<sup>-1</sup> was synthesized by a one-step, in situ, and industrially-oriented spray pyrolysis method using iron lactate and sucrose solution as the precursors. The small  $\alpha$ -Fe<sub>2</sub>O<sub>3</sub> nanocrystals were highly dispersed inside amorphous carbon to form a carbon nanocomposite. Electrochemical measurements showed that the carbon played an important role in affecting both the cycle life and the rate capability of the electrode. The HIOC composites showed the best electrochemical performance in terms of high capacity (1210 mAh g<sup>-1</sup> at a current density of 0.1 C), enhanced rate capability and excellent cycle stability (720 mAh g<sup>-1</sup> at a current density of 2 C up to 220 cycles). HIOC nanocomposite can also be used in other potential applications, such

as in gas sensors, catalysts, and biomedical applications because it is easily dispersed in water and has a high surface area.

A nanocrystalline Li<sub>4</sub>Ti<sub>5</sub>O<sub>12</sub>-TiO<sub>2</sub> duplex phase has been synthesized by a simple basic molten salt process (BMSP) using a eutectic mixture of LiNO<sub>3</sub>-LiOH-Li<sub>2</sub>O<sub>2</sub> at 400–500 °C. The microstructure and morphology of the Li<sub>4</sub>Ti<sub>5</sub>O<sub>12</sub>-TiO<sub>2</sub> product are characterized by means of X-ray diffraction, field emission scanning electron microscopy, and transmission electron microscopy. The sample prepared by heat-treating at 300 °C for 3 h (S-1) reveals dense agglomerates of ultra-fine nanocrystalline Li<sub>4</sub>Ti<sub>5</sub>O<sub>12</sub>; with heat treatment at 400 °C for 3 h (S-2), there is a duplex crystallite size (fine < 10 nm, and coarse > 20 nm) of Li<sub>4</sub>Ti<sub>5</sub>O<sub>12</sub>-TiO<sub>2</sub>; at 500 °C for 3 h (S-3), a much coarser and less-dense distribution of lithium titanate (crystallite size ~ 15–30 nm) is observed. According to the results of electrochemical testing, the S-2 sample shows initial discharge capacities of 193 mAhg<sup>-1</sup> at 0.2 C, 168 mAhg<sup>-1</sup> at 0.5 C, 146 mAhg<sup>-1</sup> at 1 C, 135 mAhg<sup>-1</sup> at 2 C, and 117 mAhg<sup>-1</sup> at 5 C. After 100 cycles, the discharge capacity is 138 mAhg<sup>-1</sup> at 1 C with capacity retention of 95%. The S-2 sample yields the best electrochemical performance in terms of charge–discharge capacity and rate capability compared with other samples. Its superior electrochemical performance can be mainly attributed to the duplex crystallite structure, composed of fine (<10 nm) and coarse (>20) nm nanoparticles, where lithium ions can be stored within the grain boundary interfaces between the spinel Li<sub>4</sub>Ti<sub>5</sub>O<sub>12</sub> and the anatase TiO<sub>2</sub>.

Lithium copper tin silicon oxide was prepared from their precursor compounds using Brij surfactant and different sources

of Si such as SiO<sub>2</sub>, SiC, and Si<sub>3</sub>N<sub>4</sub>. A hydrothermal autoclave method was used in the first stage of the preparation. X-ray diffraction characterization revealed that the crystal structures of these compounds were tetragonal. Scanning electron microscope investigation showed that the particle size morphology of Li<sub>2</sub>CuSnSiO<sub>6</sub> is larger than that of Li<sub>2</sub>CuSnO<sub>4</sub>. Electrochemical impedance spectroscopy explained that the cell prepared from the Li<sub>2</sub>CuSnSiO<sub>6</sub> electrode using Si<sub>3</sub>N<sub>4</sub> precursor had a lower charge-transfer resistance (38Ω) than that of Li<sub>2</sub>CuSnO<sub>4</sub> (R<sub>ct</sub> = 2936Ω). Furthermore, the reversible specific discharge capacity of the Li<sub>2</sub>CuSnSiO<sub>6</sub> cell was 870 mAh/g in comparison with 780 mAhg<sup>-1</sup> for the Li<sub>2</sub>CuSnO<sub>4</sub> cell after 100 cycles.

A novel VO<sub>2</sub>(B)-multiwall carbon nanotube (MWCNT) composite with a sheet-like morphology was synthesized by a simple in situ hydrothermal process. The morphology and structural properties of the samples were investigated by X-ray diffraction, thermogravimetric analysis, field emission scanning electron microscopy, and transmission electron microscopy. FE-SEM observations demonstrated that the nanosheets are frequently grown together in the form of bundles composed of numerous nanosheets, each with a smooth surface and a typical length of 300–500 nm, width of 50–150 nm, and thickness of 10–50 nm. Electrochemical measurements were carried out using different discharge cut-off voltages. Electrochemical tests show that the VO<sub>2</sub>(B)-MWCNT composite cathode features long-term cycling stability and high discharge capacity (177 mAhg<sup>-1</sup>) in the voltage range of 2.0–3.25V at 1 C with a capacity retention of 92% after 100 cycles. The electrochemical impedance spectra (EIS) indicate that the VO<sub>2</sub>(B)-MWCNT composite electrode

has very low charge-transfer resistance compared with pure  $\text{VO}_2(\text{B})$ , indicating the enhanced ionic conductivity of the  $\text{VO}_2(\text{B})$ -MWCNT composite. The enhanced cycling stability is attributed to the fact that the  $\text{VO}_2(\text{B})$ -MWCNT composite can prevent the aggregation of active materials, accommodate the large volume variation, and maintain good electronic contact. We strongly believe that the  $\text{VO}_2(\text{B})$ -MWCNT composite can be considered as a potential cathode material for lithium-ion batteries.

#### PUBLICATIONS

1. S. L. Chou, Y. Zhao, J. Wang, H. K. Liu, and S. X. Dou, "Silicon/single-walled carbon nanotube composite paper as a flexible anode material for lithium ion batteries", *Journal of Physical Chemistry C* 114, 15862 (2010).
2. S. L. Chou, J. Wang, M. Choucair, H. K. Liu, J. A. Stride, and S. X. Dou, "Enhanced reversible lithium storage in a nanosize silicon/graphene composite", *Electrochemistry Communications* 12, 303 (2010).
3. S. L. Chou, J. Wang, D. Wexler, K. K. Konstantinov, C. Zhong, H. K. Liu, and S. X. Dou, "High-surface-area  $\alpha\text{-Fe}_2\text{O}_3$ /carbon nanocomposite: one-step synthesis and its highly reversible and enhanced high-rate lithium storage", *Journal of Materials Chemistry* 20, 2092 (2010).
4. M. Hassan, Md. M. Rahman, Z. P. Guo, Z. Chen, and H. K. Liu, "Solvent-assisted molten salt process: A new route to synthesise  $\alpha\text{-Fe}_2\text{O}_3/\text{C}$  nanocomposite and its electrochemical performance in lithium-ion batteries", *Electrochimica Acta* 55, 5006 (2010).
5. M. F. Hassan, Z. P. Guo, Z. Chen, and H. K. Liu, "Carbon-coated  $\text{MoO}_3$  nanobelts as anode materials for lithium-ion batteries", *Journal of Power Sources* 195, 2372 (2010).
6. H. K. Liu, Z. P. Guo, J. Wang, and K. Konstantinov, "Si-based anode materials for lithium rechargeable batteries", *Journal of Materials Chemistry* 20, 10055 (2010).
7. M. M. Rahman, J. Z. Wang, M. F. Hassan, S. L. Chou, D. Wexler, and H. K. Liu, "Basic molten salt process (BMSP) -A new route for the synthesis of nano-crystalline  $\text{Li}_4\text{Ti}_5\text{O}_{12}\text{-TiO}_2$  anode material for Li-ion battery using the eutectic mixture of  $\text{LiNO}_3\text{-LiOH-Li}_2\text{O}_2$ ", *Journal of Power Sources* 195, 4297 (2010).
8. L. Noerochim, J. Z. Wang, S. L. Chou, H. J. Li, and H. K. Liu, "SnO<sub>2</sub>-coated multiwall carbon nanotube composite anode materials for rechargeable lithium-ion batteries", *Electrochimica Acta* 56, 314 (2010).
9. A. Shenouda and H. K. Liu, "Preparation, characterization and electrochemical performance of  $\text{Li}_2\text{CuSnO}_4$  and  $\text{Li}_2\text{CuSnSiO}_6$  electrodes for lithium batteries", *Journal of the Electrochemical Society* 157, A1183 (2010).

## Discovery Projects

### Current limiting mechanisms in magnesium diboride superconductors

<b>Funded:</b>	2007 2008 2009 2010 2011
<b>Project ID:</b>	DP0770205
<b>Chief</b>	S. X. Dou
<b>Investigators:</b>	
<b>Partner</b>	J. Driscoll, R.
<b>Investigators:</b>	Flukiger, H. Kumakura, M. Sumption

#### PROGRESS MADE IN 2010

The aim of this project is the understanding of mechanisms responsible for the significant enhancement in  $J_c$ ,  $H_{irr}$  and  $H_{c2}$ . Research project in 2010 proceeded as planned. We have further investigated superconducting properties of  $\text{MgB}_2$  samples.

In-field  $J_c$  improvement by oxygen-free pyrene gas diffusion into highly dense  $\text{MgB}_2$  superconductor: Oxygen-free pyrene gas as a carbon (C) dopant was delinked and incorporated into highly dense  $\text{MgB}_2$  structure via a gas phase diffusion method. The technique offers the advantages that molecular C is homogeneously distributed

into  $\text{MgB}_2$  and substituted at the boron sites without any severe deterioration of grain connectivity. High disorder is introduced into the samples with C substitution. The introduction such structural disorder leads to a considerable enhancement of the in-field critical current density ( $J_c$ ) and upper critical field.

Enhancement of  $J_c$  and  $H_{irr}$  by  $\text{SiCl}_4$  doping: A doping source for  $\text{MgB}_2$ , liquid  $\text{SiCl}_4$ , which is free of C, was introduced to significantly enhance the irreversibility field,  $H_{irr}$ , the upper critical field,  $H_{c2}$ , and the critical current density  $J_c$  with a little reduction in the critical temperature  $T_c$ . Although Si cannot be incorporated into the crystal lattice, a significant reduction in the a-axis

lattice parameter was found, to the same extent as for carbon doping. Based on the first-principles calculation, it is found that it is reliable to estimate the C concentration just from the reduction in the a-lattice parameter for C-doped MgB<sub>2</sub> polycrystalline samples that are prepared at high sintering temperatures, but not for those prepared at low sintering temperatures. It was found that spatial variation in the charge-carrier mean free path is responsible for the flux-pinning mechanism in the SiCl<sub>4</sub> treated MgB<sub>2</sub> with large in-field J<sub>c</sub>.

Influence of hydrogen containing argon gas on the structural parameters and superconducting properties of malic acid-doped MgB<sub>2</sub> wires: We have studied the influence of hydrogen containing argon gas on the structural and superconducting properties of MgB<sub>2</sub> wires. Lattice parameters were independent of the concentration level of hydrogen in argon, while the fraction of the secondary phase, MgO, was sensitive. The MgO particles observed by scanning transmission electron microscopy were 30-50 nm in size, which is considerably larger than the appropriate size range of flux pinning centers. The sintering atmosphere conditions are a crucial issue for MgB<sub>2</sub> wires.

Magnetic field processing: The mechanism of magnetic field sintering on the critical transition temperature, T<sub>c</sub>, for the Zn doped MgB<sub>2</sub> superconductor was investigated with the observation of Raman scattering measurement and the Raman spectra fit analysis. The broadened E<sub>2g</sub> mode in Raman spectra shows the strengthening of the electron-phonon coupling (EPC) for the sample sintered in magnetic field. A synchronous fluctuation is observed between the Raman characters of the E<sub>2g</sub> mode and the T<sub>c</sub>.

## PUBLICATIONS

1. S. R. Ghorbani, X. L. Wang, M. S. A. Hossain, S. X. Dou and S. I. Lee, "Coexistence of the delta I and delta T-c flux pinning mechanisms in nano-Si-doped MgB<sub>2</sub>", Superconductor Science and Technology 23, 025019 (2010).
2. W. X. Li, R. Zeng, C. K. Poh, Y. Li, and S. X. Dou, "Magnetic scattering effects in two-band superconductor: the ferromagnetic dopants in MgB<sub>2</sub>", Journal of Physics-Condensed Matter 22, 135701 (2010).
3. C. C. Wang, C. Wang, R. Zeng and S. X. Dou, "Intergrain connectivity of MgB<sub>2</sub> ceramics studied by impedance analysis", Journal of Applied Physics 108, 023901 (2010).
4. X. L. Wang, S. X. Dou, M. S. A. Hossain, Z. X. Cheng, X. Z. Liao, S. R. Ghorbani, Q. W. Yao, J. H. Kim and T. Silver, "Enhancement of the in-field J<sub>c</sub> of MgB<sub>2</sub> via SiCl<sub>4</sub> doping", Physical Review B 81, 224514 (2010).

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

<b>Funded:</b>	2008
	2009
	2010
<b>Project ID:</b>	DP0879714
<b>Chief</b>	G. Peleckis
<b>Investigators:</b>	

## PROGRESS MADE IN 2010

In 2010 we have continued our research on ZnO oxide as potential candidate for high temperature thermoelectric applications. We have based our investigations on the preliminary data obtained in 2009, where we have incorporate Ga into the ZnO

crystal lattice. Our further work included significant theoretical and fundamental understanding on the mechanisms responsible for the improved Seebeck coefficient values in Ga doped ZnO. In thermoelectric materials, a close correlation exists between electrical conductivity and Seebeck coefficient. This correlation can be expressed through so called Jonker plot. This graphical representation can give important information on the thermoelectric performance of given material at different temperatures. For our samples we found that there is a good agreement in Seebeck coefficient values and electrical conductivity at high temperatures, but there is a significant discrepancy in the data at room temperatures. This discrepancy could be caused by positive variation in charge carrier mobility with respect to conductivity. A depression in the Jonker plot slope at room temperature suggests a direct proportionality between mobility and conductivity or carrier concentration. Another possible reason for this discrepancy could be grain boundary effect, where carriers are trapped.

Also, we have successfully extended our work in fabrication of nano-particle based ZnO material. For enhancement of thermoelectric properties we have introduced Al. Samples have been prepared by scalable and rapid microwave mediated aminolytic reaction between zinc salts and oleylamine (surfactant) together with the dopant containing Al salt. We have found that resulting products are in fact ZnO/ZnAl<sub>2</sub>O<sub>4</sub> nanocomposites. Nanocomposites are known to have low thermal conductivity, while pertaining Seebeck coefficient and electrical conductivity, thus we have focused on the study of this nanocomposite. Thermal conductivity for our nanocrystalline samples has been significantly decreased. The thermal conductivity of undoped ZnO is 7 W/mK which is about 6 times lower than the

bulk value of 40 W/mK. Such low value of thermal conductivity is possibly a result of increased number of grain boundaries due to small crystallite size of ~ 100nm. With Al doping, thermal conductivity decreases even further, to 1.5 W/mK at 2% doping level. Such significantly reduced thermal conductivity results from large number of grain boundaries, but also can be attributed to Al, which also works as scattering agent.

We have further investigated formation of thin films of PbPdO<sub>2</sub> compound, which shows interesting metal-insulation transition and intermediate temperatures and also promising thermoelectric properties. We have found that film prepared in N<sub>2</sub> atmosphere are actually textured PbPd<sub>3</sub> alloys, with extremely low electrical resistivity, <80 mΩ/cm at room temperature. Furthermore, these samples have large MR effect even at room temperature, ~10%. This is the first work on PbPd<sub>3</sub> textured thin films.

## PUBLICATIONS

1. P. Jood, G. Peleckis, X. L. Wang, S. X. Dou, H. Yamauchi, and M. Karppinen, "Phase formation and magnetotransport of alkali metal doped Na<sub>0.75</sub>CoO<sub>2</sub> thermoelectric oxide", *Journal of Applied Physics* 107, 09D716 (2010).

## Giant magnetocaloric materials and room temperature refrigeration

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

## PROGRESS MADE IN 2010

In year 2010 we have continued to investigate a range of materials having potential for room temperature magnetocaloric applications. Below are some of the results obtained during 2010.

Three first order magnetic phase transitions in re-entrant ferromagnet PrMn<sub>1.4</sub>Fe<sub>0.6</sub>Ge<sub>2</sub>

Three first order magnetic phase transitions (FOMTs) have been detected and evaluated over the temperature range from 5 to 340K at fields up to 9 T in PrMn<sub>1.4</sub>Fe<sub>0.6</sub>Ge<sub>2</sub>. All three FOMTs, from (with decreasing temperature) an antiferromagnetic (AFI) to a c-axis canted ferromagnetic (Fmc) state, to a c-axis canted antiferromagnetic (AFmc) state, and then to an Fmc state plus an additional Pr-sublattice magnetic contribution (Fmc + F(Pr)), exhibited temperature and field-induced transition features. Based on systematic measurements and analysis, a magnetic phase diagram has been determined.

Large magnetic entropy change near room temperature in La<sub>0.7</sub>(Ca<sub>0.27</sub>Ag<sub>0.03</sub>)MnO<sub>3</sub> perovskite

Magnetic property and magnetocaloric effect (MCE) of La<sub>0.7</sub>(Ca<sub>1-x</sub>Ag<sub>x</sub>)MnO<sub>3</sub> (0 < x < 1.0) have been reported. Magnetization measurements versus temperature showed that all our samples exhibit a paramagnetic to ferromagnetic transition with decreasing temperature. The Curie temperature T<sub>c</sub> is found to increase from ~250 K for x = 0 to ~270 K for x = 1. Ag doping weakens the first order phase transition and at higher Ag doping the phase transition is of second order. The relative cooling power RCP without hysteresis loss are about 102 J/kg and 271 J/kg for the applied field 2 T and 5 T respectively. Due to large (S<sub>m</sub>), RCP and high Curie temperature, the La<sub>0.7</sub>(Ca<sub>0.27</sub>Ag<sub>0.03</sub>)MnO<sub>3</sub> is promising candidate for refrigeration applications.

Large magnetocaloric effect in re-entrant ferromagnet PrMn<sub>1.4</sub>Fe<sub>0.6</sub>Ge<sub>2</sub>

Magnetocaloric effects (MCE) at multiple magnetic phase transition temperatures in PrMn<sub>1.4</sub>Fe<sub>0.6</sub>Ge<sub>2</sub> were investigated by heat capacity and magnetization measurements. A large magnetic entropy change (– SM) 8.2 J/kgK and adiabatic temperature change (T<sub>ad</sub>) 4.8K are observed for a field change of 0–1.5 T around 25.5 K, associated with the field-induced first order magnetic phase transition (FOMT) from the antiferromagnetic to the ferromagnetic state with an additional Pr magnetic contribution. These results suggest that a re-entrant ferromagnet is probably promising candidate as working material in the hydrogen and nature gas liquefaction temperature range magnetic refrigeration technology.

## PUBLICATIONS

1. J. C. Debnath, R. Zeng, J. H. Kim, and S. X. Dou, "Giant magnetic entropy change of colossal magnetoresistance in La<sub>0.7</sub>Ca<sub>0.3</sub>MnO<sub>3</sub> material in low field", *Journal of Applied Physics* 107, 09A916 (2010).
2. P. Shamba, R. Zeng, J. Q. Wang, and S. X. Dou, "A sign of field-induced first order magnetic state transition and giant reversible magnetocaloric effect in cobalt hydroxide nanosheets", *Journal of Applied Physics* 107, 09A919 (2010).
3. R. Zeng, J. L. Wang, L. Lu, W. X. Li, S. J. Campbell, and S.X. Dou, "Three first order magnetic phase transitions in re-entrant ferromagnet PrMn<sub>1.4</sub>Fe<sub>0.6</sub>Ge<sub>2</sub>", *Journal of Alloys and Compounds* 505, L38 (2010).

4. J. C. Debnath, R. Zeng, J. H. Kim, and S. X. Dou, "Improvement of refrigerant capacity of  $\text{La}_{0.7}\text{Ca}_{0.3}\text{MnO}_3$  material with a few percent Co doping", Journal of Magnetism and Magnetic Materials 323, 139 (2011).

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

<b>Funded:</b>	2008 2009 2010
<b>Project ID:</b>	DP0878661
<b>Chief</b>	X. B. Yu
<b>Investigators:</b>	

#### PROGRESS MADE IN 2010

1.  $\text{NaBH}_4$  was destabilised by using  $\text{CaH}_2$  or  $\text{Ca}(\text{BH}_4)_2$ . Temperature programmed desorption (TPD) experiments revealed a significant improvement in the decomposition temperature and the rate of desorption, as well as the weight percentage of hydrogen released from composites with the additive upon heating to 500 °C.
2. The effect of hydrogen back-pressure on the de/rehydrogenation kinetics of the  $\text{LiBH}_4$ - $\text{MgH}_2$  system was studied systematically. The results showed that a static vacuum allows fast desorption kinetics along with the formation of the main phases of boron, Mg, or Li-Mg alloy, but performance is compromised by slow absorption kinetics.
3. The hydrogen de/resorption of the  $2\text{LiBH}_4$ + $\text{MgH}_2$  system was modified by introducing Ni nanoparticles. Dehydrogenation analysis revealed that the first-step dehydrogenation, i.e. the decomposition of  $\text{MgH}_2$ , can be significantly promoted by adding a small amount of Ni due to the catalytic effect.

4.  $\text{TiF}_3$  was doped into the  $\text{LiAlH}_4$ + $\text{MgH}_2$  composite for promoting this interaction and thus enhancing the hydrogen sorption properties. Experimental analysis on the  $\text{LiAlH}_4$ - $\text{MgH}_2$ - $\text{TiF}_3$  composite revealed that the dehydrogenation temperature of this system starts from about 60 °C, which is 100 °C lower than for  $\text{LiAlH}_4$ - $\text{MgH}_2$ .
5. Ruthenium nanoparticles supported on multiwalled carbon nanotubes (Ru/C) were prepared and their effect on the hydrogen sorption properties of  $\text{LiBH}_4$ - $\text{MgH}_2$  systems was investigated. The experimental results showed that the Ru/C catalyst is active in reducing the dehydrogenation temperature and enhancing the dehydrogenation kinetics.
6. A novel combined hydrogen storage system  $\text{LiBH}_4$ /[ $\text{C}(\text{NH}_2)_3^+[\text{BH}_4]^-$ ] (GBH) complexes was reported. By a short time ball milling of  $\text{LiBH}_4$  and guanidinium chloride, a series of new  $\text{LiBH}_4$ /GBH complexes were produced. It was found that the two potential hydrogen storage materials exhibited a mutual dehydrogenation improvement, releasing >10.0 wt% fairly pure  $\text{H}_2$  from  $\text{LiBH}_4$ /GBH below 250 °C.

#### PUBLICATIONS

1. J. F. Mao, Z. P. Guo, X. B. Yu, and H. K. Liu, International Journal of Hydrogen Energy, in press, accepted 01/02/2011
2. J. F. Mao, Z. P. Guo, X. B. Yu, and H. K. Liu, Journal of Alloys and Compounds, in press, accepted 01/02/2011
3. Y. H. Guo, Q. F. Gu, Z. P. Guo, J. F. Mao, H. K. Liu, S. X. Dou, and X. B. Yu, Journal of Materials Chemistry, in press, accepted 22/02/2011

### Novel graphene nanostructures: modelling, synthesis, fabrication and characterization

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

#### PROGRESS MADE IN 2010

We have achieved the following outcomes in 2010:

1. We have determined the critical field required for the nonlinear effect to be dominant in bilayer graphene. This nonlinear effect can be used to enhance the light absorption and emission through up-conversion and down-conversion.
2. We have shown that a new class of materials can exist in graphene under controlled hydrogenation. In this material, the band structure is gapless but the optical response is strictly forbidden. We refer this to a gapless insulator.
3. Through simulation, we demonstrated that there exists a frequency regime in which a graphene junction exhibits negative ac conductivity. This negative ac conductivity implies a light amplification mechanism in graphene p-n junctions.
4. We have performed a first principle study of electron-phonon interaction and phonon mediated optical response in graphene. Temperature and frequency dependent optical response has been derived.
5. The absorption edge and the temperature dependent resistivity in semi-hydrogenated graphene has been quantitatively determined.
6. We have studied the solution behaviour of chemically converted graphene using gold nanoparticles as a plasmonic probe and demonstrated the unique

use of graphene oxide as a soluble, rigid substrate for nanoparticles assembly, which has solved a long-standing problem in catalysis and nanoplasmonics. The result has been accepted for publication in an A\* journal.

7. We have studied the solution behaviour of graphene oxide and chemically converted graphene using the capillary zone electrophoresis technique. The result has been published in an A\* journal.
8. We have further characterized the configuration of chemically converted graphene in water using liquid-phase AFM. A manuscript has been recently submitted to an A\* journal.

We have studied the nonlinear optical transmission of graphene and its composites. The result has been published in an A journal.

## PUBLICATIONS

1. Y. S. Ang, S. Sultan, and C. Zhang, "Nonlinear optical spectrum of bilayer graphene in the terahertz regime", *Applied Physics Letters* 97, 243110 (2010).
2. A. R. Wright, T. E. O'Brien, D. Beaven, and C. Zhang, "Gapless insulator and a band gap scaling law in semi-hydrogenated graphene", *Applied Physics Letters* 97, 043104 (2010).
3. X. G. Xu, S. Sultan, C. Zhang, and J. C. Cao, "Nonlinear optical conductance in a graphene pn junction in the terahertz regime", *Applied Physics Letters* 97, 011907 (2010).
4. G. J. Xu, X. G. Xu, B. H. Wu, J. C. Cao, and C. Zhang, "The resonant tunnelling through a graphene multi-quantum well system", *Journal of Applied Physics* 107, 123718 (2010).

5. A. R. Wright and C. Zhang, "Dynamic conductivity of graphene with electron-LO-phonon interaction", *Physical Review B* 81, 165413 (2010).
6. L. Chen, Z. S. Ma, and C. Zhang, "Vertical absorption edge and temperature dependent resistivity in semi-hydrogenated graphene", *Applied Physics Letters* 96, 023107 (2010).
7. F. L. Bei, X. L. Hou, S. Chang, G. G. Simon, and D. Li, "Interfacing colloidal graphene oxide sheets with gold nanoparticles", *Chemistry – A European Journal*, in press, accepted 02/2011.
8. B. S. Zhao, B. B. Cao, W. L. Zhou, D. Li, and W. Zhao, "Nonlinear optical transmission of nanographene and its composites", *Journal of Physical Chemistry C* 114, 12517 (2010).
9. M. B. Muller, J. P. Quirino, P. N. Nesterenko, P. R. Haddad, S. Gambhir, D. Li, and G. G. Wallace, "Capillary zone electrophoresis of graphene oxide and chemically converted graphene", *Journal of Chromatography A* 1217, 7593 (2010).

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

<b>Funded:</b>	2008 2009 2010
<b>Project ID:</b>	DP0878611
<b>Chief Investigators:</b>	Z. P. Guo

### PROGRESS MADE IN 2010

Three-dimensional (3D) anodes have been prepared for lithium ion microbatteries by depositing SnO<sub>2</sub> nanocrystals into self-organised TiO<sub>2</sub> nanotube arrays through the solvothermal method, with the SnO<sub>2</sub> crystal size less than 5 nm. The 3D SnO<sub>2</sub>-TiO<sub>2</sub> anodes exhibit excellent electrochemical

performance with good capacity retention of up to 70.8% over 100 cycles in the voltage range of 0.05-2.5 V. SnO<sub>2</sub> enhances the capacity to more than double that of bare TiO<sub>2</sub>, while TiO<sub>2</sub> nanotubes accommodate the volume changes of SnO<sub>2</sub> during charge/discharge cycling. The amount of SnO<sub>2</sub> loading can be controlled by varying the reaction time. The capacity of the 3D electrodes is controlled by the TiO<sub>2</sub> tube length as well as by the amount of SnO<sub>2</sub> loading. The maximum reversible capacity of the present samples can reach as high as about 300 mAh/cm<sup>2</sup>.

Restacked MoS<sub>2</sub> with enlarged c lattice parameter and surface area was prepared by exfoliation and restacking process, exhibiting high reversible lithium storage capacity and superior rate capability as anode material for lithium ion batteries.

Thin films of lithium cobalt oxide were deposited on Pt or Pt/Ti/quartz glass substrates by radio frequency (RF) magnetron sputtering at the substrate temperatures from room temperature to 500 degrees C. As the substrate temperature increased, the film structure changed from amorphous structure to crystallinity with a strong (003) texture as characterised by X-ray diffraction. The surface morphology and cross-section were observed using scanning electron microscopy. It was found that the films tended to crack at a high substrate temperature. Charge-discharge tests of these films were conducted and compared. The different electrochemical characteristics of these films were attributed to the modified crystallography, morphology, and thermal stress. The LiCoO<sub>2</sub> film deposited at 400 degrees C showed a well-defined 4.0 V voltage plateau on charge and a 3.9 V plateau on discharge, and delivered 54.5 mAh/cm<sup>2</sup> mu m at the first discharge capacity, with good cycling performance,

giving evidence that such films could be used as the thin film cathodes for lithium microbatteries.

## PUBLICATIONS

1. G. D. Du, Z. P. Guo et al., "Superior stability and high capacity of restacked molybdenum disulfide as anode material for lithium ion batteries", *Chemical Communications* 46, 1106 (2010).
2. J. Liu, W. Wang, Z. P. Guo et al., "Peashell-like nanostructure – A new kind of one-dimensional nanostructure: the case of magnesium oxide", *Chemical Communications* 46, 3887 (2010).
3. C. Q. Feng, L. Li, Z. P. Guo, and H. Li," Synthesis and characterization of tin dioxide/multiwall carbon nanotube composites", *Journal of Alloys Compounds* 504, 457 (2010).
4. G. D. Du, Z. P. Guo et al., "SnO<sub>2</sub> nanocrystals on self-organized TiO<sub>2</sub> nanotube array as three-dimensional electrode for lithium ion microbatteries", *Journal of Materials Chemistry* 20, 5689 (2010).
5. G. D. Du, C. Zhong, P. Zhang, Z. P. Guo, Z. X. Chen, and H. K. Liu, *Electrochimica Acta* 55, 2582 (2010).
6. B. Liu, Z. P. Guo et al., "In-situ synthesis of ultra-fine porous tin oxide-carbon nanocomposites via a molten salt method for lithium ion batteries", *Journal of Power Sources* 195, 5382 (2010).
7. X. J. Zhu, Z. P. Guo, G. D. Du, P. Zhang, and H. K. Liu, "LiCoO<sub>2</sub> cathode thin film fabricated by RF sputtering for lithium ion microbatteries", *Surface and Coatings Technology* 204, 1710 (2010).

8. J. Q. Wang, B. Liu, G. D. Du, R. Zeng, Z. X. Chen, Z. P. Guo, and S. X. Dou, *Materials Chemistry and Physics*, in press (available on line on 12 Jan. 2011).
9. C. F. Zhang, M. Quince, Z. X. Chen, Z. P. Guo, and H. K. Liu, "3-Dimensional nanocarbon and the electrochemistry of nanocarbon/tin oxide for lithium ion batteries", *Journal of Solid-State Electrochemistry*, in press (accepted on 15/11/2010).

## Fabrication of high quality MgB<sub>2</sub> superconductor

<b>Funded:</b>	2008 2009 2010
<b>Project ID:</b>	DP0879843
<b>Chief</b>	S. H. Zhou
<b>Investigators:</b>	

### PROGRESS MADE IN 2010

A modified inner diffusion powder-in-tube (PIT) method was used to make MgB<sub>2</sub> wires, the critical current density J<sub>c</sub> reached 10<sup>4</sup>A/cm<sup>2</sup> at 8 T and 5 K. Carbon was doped into MgB<sub>2</sub> by reaction in the mixture of CO and CO<sub>2</sub> gases. Electromagnetic measurements revealed that J<sub>c</sub> was slightly improved, while T<sub>c</sub> dropped as a result of the doping.

## PUBLICATIONS

1. S. H. Zhou and S. X. Dou, "Properties of MgB<sub>2</sub> bulks after combined doping with Fe and C by adding iron(II)lactate (C<sub>6</sub>H<sub>10</sub>FeO<sub>6</sub>)", *Solid State Sciences* 12, 105 (2010).
2. S. H. Zhou, Y. Zhang, and S. X. Dou, "Effects of B<sub>2</sub>O<sub>3</sub> in precursor B powder on MgB<sub>2</sub> critical current density", *Physica C* 470, S635 (2010).
3. R. Zeng, S. Zhou, L. Lu, W. X. Li, and S. X. Dou, "Synthesis and characteristics of MgB<sub>2</sub> bulks with different densities", *Physica C* 470, S669 (2010).

## Frustrated magnets: a new platform for multiferroic materials

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

### PROGRESS MADE IN 2010

1) Systematic study on the Er doping effects on the structural, dielectric, ferroelectric, magnetic, and thermal properties of the hexagonal Ho<sub>1-x</sub>Er<sub>x</sub>MnO<sub>3</sub> compounds have been investigated by Rietveld refinement and by measurements of dielectric constant, ferroelectric hysteresis loops, magnetic susceptibility, and specific heat. The a lattice parameter decreases as the Er content increases, whereas the c lattice parameter nearly keeps constant with pretty minor fluctuations. Dielectric data and ferroelectric hysteresis loops show all the samples are not only ferroelectric materials with leaky nature, but also with dielectric relaxation related to oxygen vacancies. The magnetizations of these compounds gradually decrease with increasing Er content. The Mn<sup>3+</sup> ions in each sample remain stable in the high-spin state in the MnO<sub>5</sub> trigonal bipyramidal crystal field. Specific heat measurements show that the antiferromagnetic transition temperature continuously rises from 72 K for HoMnO<sub>3</sub> to 76 K for ErMnO<sub>3</sub>. The Debye temperatures are 381 K for ErMnO<sub>3</sub> and 422 K for HoMnO<sub>3</sub>. This work is currently in press in *Physical Review B* [1].

2) Double perovskite structured multiferroic Bi<sub>2</sub>FeMnO<sub>6</sub> hollow particles have been fabricated on silicon substrates from a sol-gel precursor by an electrospray method. The as-prepared Bi<sub>2</sub>FeMnO<sub>6</sub> polycrystalline samples are pure-phase, crystallizing in space group R3c. Raman spectra have

verified the vibrational frequencies in the  $\text{Bi}_2\text{FeMnO}_6$  samples. The  $\text{Bi}_2\text{FeMnO}_6$  nano-/micron-sized hollow particles show a porous shell with large interior void. The shell thickness is 100 nm. The structure and morphology of the sample were found to be controlled by the deposition time. The formation mechanism can be explained by an Ostwald ripening-Kirkendall model. The temperature dependence of the magnetization curve and magnetic hysteresis loops indicate that  $\text{Bi}_2\text{FeMnO}_6$  particles exhibit weak ferromagnetic moment at both low and room temperature [2].

3) Perovskite-type  $\text{Nd}_{1-x}\text{La}_x\text{CrO}_3$  ( $0 < x < 1.0$ ) polycrystalline samples were synthesized using solid state reaction. Structural studies indicate that the lattice parameters, metal-oxygen bond lengths, and angles of  $\text{Nd}_{1-x}\text{La}_x\text{CrO}_3$  strongly depend on the La content. Two magnetic transition temperatures,  $\text{Cr}^{3+}$  antiferromagnetic ordering temperature  $T_N$  and the spin reorientation phase transition temperature  $\text{TSRPT}$ , have been observed in the M-T curves. The increase in  $T_N$  and decrease in  $\text{TSRPT}$  with increasing  $x$  value can be explained by the change in the magnetic interactions due to La doping. The heat capacity of  $\text{Nd}_{1-x}\text{La}_x\text{CrO}_3$  measured from 2 to 300 K reveals that the lattice, electronic, and magnetic contributions to heat capacity can be well interpreted quantitatively using the Debye and Schottky models. The splitting energy of the  $\text{Cr}^{3+}$   $t_{2g}$  orbital and the  $\text{Nd}^{3+}$  ground state have been calculated by fitting to the Schottky anomaly at very low temperature. The Cr-Nd interaction is suppressed gradually by La doping, which is verified by the calculation of the mean-field interaction parameter. This doping dependence provides directed evidence of TM-RE magnetic interactions in perovskite compounds, in agreement with the proposed model [3].

4) Multiferroic  $\text{BiFe}_{1-x}\text{Cr}_x\text{O}_3$  is prepared by the hydrothermal method. Samples are systematically characterized by X-ray diffraction, Rietveld refinement, SEM, dielectric and magnetic measurements. The lattice parameters, the morphology and the size of the obtained particles strongly depend on the Cr doping level. The particle morphology changes from spherical shape for pure  $\text{BiFeO}_3$  to octahedral shape for  $x=0.1$ . The dielectric constant and the magnetization increase greatly with the increase of the Cr doping level. Both the M-T and the M-H results reveal that the Cr doping enhances the ferromagnetic state in the doped  $\text{BiFeO}_3$ . The possible reasons for the enhanced magnetic and dielectric properties are discussed briefly [4].

5) La doped rare earth ferrite was systematically studied. Structure modification by Rietveld refinement and Raman scattering was found. In addition, the doping also shifts the spin reorientation temperature to lower side [5].

## PUBLICATIONS

1. P. Liu, X. L. Wang, Z. X. Cheng, Y. Du, and H. Kimura, "Structural, dielectric, antiferromagnetic, and thermal properties of the frustrated hexagonal  $\text{Ho}_{1-x}\text{Er}_x\text{MnO}_3$  manganites", *Physical Review B* 83, 144404 (2011).
2. Y. Du, Z. X. Cheng, H. Y. Zhao, H. Kimura, P. Zhang, Z. P. Guo, and X. L. Wang, *Current Applied Physics*, in press.
3. Y. Du, Z. X. Cheng, X. L. Wang, and S. X. Dou, "Structure, magnetic, and thermal properties of  $\text{Nd}_{1-x}\text{La}_x\text{CrO}_3$  ( $0 \leq x \leq 1.0$ )", *Journal of Applied Physics* 108, 093914 (2010).
4. Y. Du, Z. X. Cheng, S. X. Dou, M. Shahbazi, and X. L. Wang, "Enhancement of magnetization and dielectric Properties of chromium-doped  $\text{BiFeO}_3$  with tunable morphologies", *Thin Solid Films* 518, e5 (2010).
5. Y. Du, Z. X. Cheng, X. L. Wang, and S. X. Dou, "Lanthanum doped multiferroic  $\text{DyFeO}_3$ : Structural and magnetic properties", *Journal of Applied Physics* 107, 09D908 (2010).

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

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

## PROGRESS MADE IN 2010

Personnel: W. Xu left the ANU to take up a Professorial appointment in China. Not eligible to be a CI, he has changed role to PI with ARC approval. In 2009 Elise Pogson began a PhD on the project, supported by the student stipend requested in the grant. Colin Bleasdale, a PhD student funded by APA has also contributed to the research. Abby Scott commenced on the project in 2010 and Evan Constable in 2011, both as PhD students funded by APAs. UOW electrical (T. Braddock), electronic (P. Ihnat) and mechanical workshop (R. Marshall et al.) technical staff also contributed to the project.

Equipment: A major equipment failure of the Coherent pump laser of the Terahertz (THz) time domain spectroscopy (TDS) system

lost much time in the second half of 2009; the Millenia pump laser was finally installed in December 2009 and is working well.

Progress: Candidate THz materials, sourced from the University of Nottingham, UK, and the Technical University of Darmstadt, Germany, were studied. Much experimental data was collected, analysed and prepared for publication. Seven journal papers were published in 2010 in high impact journals such as Applied Physics Letters and Physical Review B, as well as three refereed conference papers. The outputs in 2010 are listed below:

## PUBLICATIONS

1. A. Bruno-Alfonso, R. A. Lewis, G. Q. Hai, and R. E. M. Vickers, "Energy states of phosphorous donor in silicon in fields up to 18T", *Journal of Low Temperature Physics* 159, 226 (2010).
2. K. Radhanpura, S. Hargreaves, R. A. Lewis, L. Sirbu, and I. M. Tiginyanu, "Heavy noble gas (Kr,Xe) irradiated (111) InP nanoporous honeycomb membranes with enhanced ultrafast all-optical terahertz emission", *Applied Physics Letters* 97, 181921 (2010).
3. R. A. Lewis, "Let's talk terahertz!", *American Journal of Physics*, accepted, in print.
4. C. Lee and R. A. Lewis, "Optical rectification for terahertz generation", *Physica Status Solidi A and C*, accepted, in print.
5. K. Radhanpura, S. Hargreaves, and R. A. Lewis, "Bulk and surface-field induced optical rectification from (11N) zincblende crystals in a quasi-reflection geometry", *Physical Review B*, accepted, in print

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

<b>Funded:</b>	2009 2010 2011
<b>Project ID:</b>	DP0987805
<b>Chief</b>	J. Z. Wang
<b>Investigators:</b>	

### PROGRESS MADE IN 2010

Hollow-structured  $\alpha$ -Fe<sub>2</sub>O<sub>3</sub>/carbon (HIOC) composites were synthesised by spray pyrolysis method using iron (II) lactate solution and sucrose as the precursors. Electrochemical tests showed that the HIOC composite electrode with 14.7% carbon using sodium carboxymethyl cellulose (CMC) as a binder had the best electrochemical performance due to its high capacity (1000 mAh g<sup>-1</sup> at 0.1 C), good rate capability (700 mAh g<sup>-1</sup> at 2 C), and good cycle stability (720 mAh g<sup>-1</sup> at 2 C up to 220 cycles).

Hollow spherical NiO particles were prepared using the spray pyrolysis method. The electrochemical properties of the NiO electrodes, which contained a new type of binder, carboxymethyl cellulose (CMC), were examined for comparison with NiO electrodes with polyvinylidene fluoride (PVDF) binder. The cell with NiO-CMC electrode has a much higher discharge capacity of 547 mAh g<sup>-1</sup> compared to that of the cell with NiO-PVDF electrode, which is 157 mAh g<sup>-1</sup> beyond 40 cycles.

SnO<sub>2</sub>-coated multiwall carbon nanotube nanocomposites were synthesized by a facile hydrothermal method. The SnO<sub>2</sub>/MWCNT composites, when combined with carboxymethyl cellulose (CMC) as a binder, show excellent cyclic retention, with the high specific capacity of 473 mAh g<sup>-1</sup> beyond

100 cycles, much greater than that of the bare SnO<sub>2</sub> which was also prepared by the hydrothermal method in the absence of MWCNTs.

TiO<sub>2</sub> nanoribbons/nanotubes (TiO<sub>2</sub>-NRTs) were synthesised successfully via a reflux method followed by drying in a vacuum oven, and then, silver coated TiO<sub>2</sub> NRTs (Ag/TiO<sub>2</sub>-NRTs) were prepared by coating silver particles onto the TiO<sub>2</sub>-NRTs surface by the traditional silver mirror reaction. The results indicated that the Ag nanoparticles were uniformly deposited on the surface of the TiO<sub>2</sub> nanoribbons/nanotubes. The electrochemical properties were investigated by a variety of techniques. The rate capability and cycle durability for the Ag/TiO<sub>2</sub>-NRTs were improved compared with TiO<sub>2</sub>-NRTs.

Flexible, free-standing, paper-like, graphene-silicon composite materials have been synthesised by a simple, one-step, in-situ filtration method. The Si nanoparticles are highly encapsulated in a graphene nanosheet matrix. The electrochemical results show that graphene-Si composite film has much higher discharge capacity beyond 100 cycles (708 mAh g<sup>-1</sup>) than that of the cell with pure graphene (304 mAh g<sup>-1</sup>). The graphene functions as a flexible mechanical support for strain release, offering an efficient electrically conducting channel, while the nanosized silicon provides the high capacity.

Two types of ionic liquid electrolytes of 1 M LiTFSI in 1-ethyl-3-methyl-imidazolium bis(fluorosulfonyl)imide (EMI-FSI) and 1 M LiTFSI in 1-methyl-1-propylpyrrolidinium bis(fluorosulfonyl)imide (Py13-FSI) have been tested with transition metal oxide/carbon composites (Fe<sub>2</sub>O<sub>3</sub>/C, NiO/C and CuO/Cu<sub>2</sub>O/C). The electrochemical measurements show that the composite electrodes using Py13-FSI as electrolyte show much better electrochemical

performance than those using EMI-FSI as electrolyte in terms of reversibility. The  $\text{Fe}_2\text{O}_3/\text{C}$  composite shows the highest specific capacity and the best capacity retention ( $420 \text{ mAh g}^{-1}$ ) under a current density ( $50 \text{ mA g}^{-1}$ ) up to 20 cycles, compared with  $\text{NiO}/\text{C}$  and  $\text{CuO}/\text{Cu}_2\text{O}/\text{C}$  composites. The present research demonstrates Py13-FSI could be used as an electrolyte for transition metal oxides in lithium-ion battery.

Nanocrystalline  $\text{MnO}_2$  cathode materials were synthesised by the hydrothermal method with or without pulsed magnetic fields. It was found that the morphology of the  $\text{MnO}_2$  prepared without magnetic field has urchin-like structure, and  $\text{MnO}_2$  prepared under magnetic fields have flower-like structure. The BET surface areas were increased when the magnetic field increased. The batteries performances were improved for the samples with magnetic fields. The  $\text{MnO}_2$  prepared without magnetic field only shows a capacity of  $103.0 \text{ mAh g}^{-1}$ , while the  $\text{MnO}_2$  prepared under a magnetic field of 4 T shows  $121.8 \text{ mAh g}^{-1}$  up to 30 cycles. Above mentioned works have been published, and the publication list is attached.

### **Direct assembly and photoelectric properties of coreshell nanowire networks of $\text{PbSe-TiO}_2$ heterostructures for high efficiency low cost solar cells**

<b>Funded:</b>	2010 2011 2012
<b>Project ID:</b>	DP1096546
<b>Chief</b>	J. H. Kim, Y. Zhao, X.
<b>Investigators:</b>	Zhu, Z. Sun

#### **PROGRESS MADE IN 2010**

Controlling the agglomeration and particle size of  $\text{TiO}_2$  electrode by zeta-potential analysis: Controlling the particle size and

agglomeration of titanium dioxide ( $\text{TiO}_2$ ) in dye-sensitized solar cell is crucial for obtaining superior efficiency. In this study, different colloidal conditions, i.e. potential of hydrogen (pH), hydrolysis rate, and viscosity, were adopted to obtain the well-dispersed nanosized  $\text{TiO}_2$ . In particular, degree of agglomeration and particle size were predicted by zeta-potential analysis. Under the zeta-potential of  $\pm 20 \text{ mV}$  (1-3 pH),  $\text{TiO}_2$  particles were quite well-dispersed and tend to smaller. Solar cell efficiency of 4 % was obtained by using the well-dispersed  $\text{TiO}_2$  with 20 nm in size.

High efficiency of  $\text{PbSe}$  quantum-dot sensitized  $\text{TiO}_2$ : We have demonstrated an approach to sensitised-type solar cells, based on  $\text{TiO}_2$  and the use of  $\text{PbSe}$  quantum dot (QDs) as sensitizers.  $\text{PbSe}$  QDs were grown in site on  $\text{TiO}_2$  electrode, utilising a chemical bath deposition method. All of the photovoltaic performances will be tested.

Roll-to-roll production of large size graphene film for transparent electrode: We report the roll-to-roll production and wet-chemical doping of predominantly monolayer large size films grown by chemical vapour deposition onto flexible PET. This film can apply to electrode for solar cell.

Preparation of highly ordered mesoporous  $\text{TiO}_2$  thin film for Dye-sensitized Solar Cells (DSSC) application: The mesoporous  $\text{TiO}_2$  film applied in DSSC has a demand of small particles size, high specific surface area, fast dye and electrolyte diffusion and adsorption. A highly ordered nanostructured mesoporous film will be one of the best choices for the photoanode in DSSC.

The highly ordered porous mesoporous  $\text{TiO}_2$  thin film was prepared by evaporation induced self-assembling (EISA) technology with different surfactants like P123 and F127. Our samples show the as-prepared surface of the mesoporous thin film and the corresponding cross-sections, where

the high-ordered mesoporous channels can be observed. The pores diameter is around 7 nm in average. It shows that more than 10 times improvement on the photo-energy conversion efficiency was achieved compared to the highly-transparent commercial Solaronix  $\text{TiO}_2$  thin film under the same conditions.

Morphology controlling of  $\text{TiO}_2$  particles for photochemical applications: The morphology of  $\text{TiO}_2$  nanoparticles is extremely important in the photochemical applications and it is strongly influences the photocatalytic or photoenergy conversion performance. Therefore, a morphology that process high specific surface area and high-ratio of catalytic-active crystalline surfaces has attracted strong interest in not only the scientific community but also the industry. In our work, we propose on a novel two-phase solvent surfactant template method to prepare morphology-controllable  $\text{TiO}_2$  nanoballs. By changing the content of solvent and the concentration of precursors, versatile  $\text{TiO}_2$  nanoballs with different morphologies and diameters were obtained.

## Materials science and superconductivity in the new Fe-based high temperature superconductors

<b>Funded:</b>	2010 2011 2012 2013
<b>Project ID:</b>	DP1094073
<b>Chief</b>	X. L. Wang, G.
<b>Investigators:</b>	Peleckis, D. P. Chen
<b>Partner</b>	H. Hosono, X.
<b>Investigators:</b>	Chen, K. H. Muller, E. Muromachi, A. J. Studer

### PROGRESS MADE IN 2010

This project was officially started in September 2010 due to the delay of the agreement from partner investigators' Institutions. The following results were obtained or published in 2010:

1) We report for the first time the very strong intrinsic flux pinning and vortex avalanches in  $(\text{Ba,K})\text{Fe}_2\text{As}_2$  superconducting single crystals. We report that the  $(\text{Ba,K})\text{Fe}_2\text{As}_2$  crystal with  $T_c=32$  K shows a pinning potential,  $U_0$ , as high as 104 K, with  $U_0$  showing very little field dependence. The  $(\text{Ba,K})\text{Fe}_2\text{As}_2$  single crystals become isotropic at low temperatures and high magnetic fields, resulting in a very rigid vortex lattice, even in fields very close to  $H_{c2}$ . The isotropic rigid vortices observed in the two-dimensional  $(\text{Ba,K})\text{Fe}_2\text{As}_2$  distinguish this compound from 2D high- $T_c$  cuprate superconductors with 2D vortices. The vortex avalanches were also observed at low temperatures in the  $(\text{Ba,K})\text{Fe}_2\text{As}_2$  crystal. It is proposed that it is the K substitution that induces both almost isotropic superconductivity and the very strong intrinsic pinning in the  $(\text{Ba,K})\text{Fe}_2\text{As}_2$  crystal. This work has been selected for the August 1, 2010 issue of Virtual Journal of Applications of Superconductivity. The Virtual Journal, which is published by

the American Institute of Physics and the American Physical Society in cooperation with numerous other societies and publishers, is an edited compilation of links to articles from participating publishers, covering a focused area of frontier research.

2) We have carried the first work in the work on the pinning enhancement in  $(\text{Ba,K})\text{Fe}_2\text{As}_2$  crystal using light ion (such as carbon) implantation technique in collaborating with ANSTO. International travel awarded was given to the Professor Wang's PhD student to present this nice work at the "Fe based superconductors" symposium in March, 2011, in Tokyo, Japan. It was organised by the inventor of this new compounds, Professor Hosono, who is also the PI on this ARC DP. A patent application on this discovery is in progress.

3) The magneto-fluctuation conductivity, called excess conductivity, originated from the forming of the superconducting droplet near to the mean-field transition temperature, was measured for the optimally doped  $\text{BaFe}_{1.8}\text{Co}_{0.2}\text{As}_2$  single crystals with a critical temperature,  $T_c$ , of 24.6 K. This measurement of the excess conductivity for magnetic fields up to 9 T was compared with the thermodynamic scaling theory in the critical region, in which not only the Gaussian fluctuation but also fourth order terms of the order parameter are included. An analysis of the excess conductivity showed that the superconductivity followed three-dimensional scaling rather than two-dimensional scaling even though the sample had a layered structure.

4) We report for the first time the crystal structures, morphologies, and superconductivity in  $\text{CeO}_{1-x}\text{F}_x\text{FeAs}$  compounds which were fabricated by solid state reaction. The crystal structures were refined using Rietveld refinement. Superconducting properties such as critical temperature ( $T_c$ ), critical current density

( $J_c$ ), and upper critical field ( $H_{c2}$ ) were determined using magneto-transport and magnetic measurement over a wide range of temperature below  $T_c$ , and in magnetic fields up to 13 T.  $J_c$  is  $2 \times 10^3$  A  $\text{cm}^{-2}$  for the  $x = 0.1$  sample. However, the  $J_c$  exhibited a weak dependence on magnetic field for  $B > 1$  T and  $T = 5$  and 10 K. A peak effect in the  $J_c$  as a function of field was observed at 20 K in the  $x = 0.1$  sample. We estimate  $H_{c2}^{ab}$  of 185 T for  $\text{CeO}_{0.9}\text{F}_{0.1}\text{FeAs}$  compound. The broadening of the superconducting transition near  $T_c$  with increasing field can be well understood using the thermal activated flux flow model. The pinning potential scales as  $U_0/K_B \propto B^{-n}$  with  $n = 0.2$  for  $B < 3$  T and  $n = 0.71$  for  $B > 3$  T in the  $x = 0.1$  sample.

5) We also report our studies on the crystal structures, morphologies, and superconductivity in  $\text{LaFeAsO}_{1-x}\text{F}_x$  compounds which were fabricated by solid state reaction. The crystal structures were refined using Rietveld refinement. Superconducting properties, such as critical temperature,  $T_c$ , critical current density,  $J_c$ , and upper critical field,  $H_{c2}$ , were determined using magneto-transport and magnetic measurements over a wide range of temperature below and above  $T_c$ , and in magnetic fields up to 14 T. A peak effect in the  $J_c$  versus field is observed at  $T < 15$  K. Upper critical field in the ab and c directions is  $H_{c2}^{ab} = 122.8$  T and  $H_{c2}^c = 38.6$  T, respectively.

### PUBLICATIONS

1. X. L. Wang et al., "Very strong intrinsic flux pinning and vortex avalanches in  $(\text{Ba,K})\text{Fe}_2\text{As}_2$  superconducting single crystals", *Physical Review B* 82, 024525 (2010).

2. M. Shahbazi et al., "Upper critical field, critical current density and thermally activated flux flow in fluorine doped CeFeAsO superconductors", *Superconductor Science & Technology* 23, 105008 (2010).
3. M. Shahbazi et al., "Superconductivity and critical current density in LaFeAsO<sub>1-x</sub>F<sub>x</sub> compounds", *Thin Solid Films* 518, 42 (2010).
4. S. H. Kim et al., "Fluctuation conductivity of single-crystalline BaFe<sub>1.8</sub>Co<sub>0.2</sub>As<sub>2</sub> in the critical region", *Journal of Applied Physics* 108, 063916 (2010).

### Advanced nanostructured ceramic composites for ultracapacitors

<b>Funded:</b>	2010 2011 2012
<b>Project ID:</b>	DP1093952
<b>Chief</b>	K. Konstantinov, H.
<b>Investigators:</b>	K. Liu, A. Calka, D. Wexler

#### PROGRESS MADE IN 2010

We have synthesised self-organised titania nanotubes and nanocrystalline titania powders employing an alternative and novel approach. Integrating these nanostructures in a binder-free working electrode improved the capacitance up to 911  $\mu\text{F}/\text{cm}^2$ , which are around one to two orders of magnitude higher than the conventional electric double layer capacitors. The paper is in press in *Physical Chemistry Chemical Physics* (IF 4.116) [1].

We have developed a facile method for the fabrication of self-organized titania nanotubes grown by anodic oxidation of titanium foil with different subsequent heat-treatment regimes for use as binder-free working electrodes in supercapacitor applications. The capacitance of these highly ordered titania nanotubes, when

exposed to a reductive atmosphere during annealing, was determined to be well above 900  $\mu\text{F}/\text{cm}^2$ , confirming that the capacitance contribution was pseudocapacitive in nature. The behaviour of oxygen depleted titania in the anatase to rutile phase transformation and also in electrochemical charge storage has been studied in detail. It was found that upon the reduction of Ti<sup>+4</sup> to Ti<sup>+3</sup>, with oxygen depletion of the structure, the A->R phase transformation was promoted. In addition, the fabricated electrodes showed highly reversible charge-discharge stability. The paper is in press in *Journal of Materials Chemistry* (IF 4.795) [2].

We have performed a breakthrough research on GO/MWCNTs composite (GO stands for graphene oxide MWCNT stands for multi-wall carbon nanotubes) as potential electrode materials for supercapacitors. We created a robust and superior hybrid material with higher capacitance compared to either graphene oxide or MWCNTs. Specific capacitances about 251F/g were obtained. Most important, a 120% increase in capacitance is observed with increasing the cycle number to 1000 cycles. The ease of synthesis and the exceptional electrochemical properties make the use of this nanostructure an attractive, alternative way of designing future supercapacitors in both conventional fields and new emerging areas. The article is being considered for publishing in *Energy & Environmental Science* (IF 8.5) after a major technical revision [3].

Finally, we have developed new types of Metal Oxide (MO) graphene products (GP) composites using our non-conventional spray pyrolysis technology. The results are considered to have important IP value and first materials demonstrate performance of

about 650 F/g. A Provisional Patent and publication in a top rank journal are currently prepared.

#### PUBLICATIONS

1. M. Salari, S. H. Aboutalebi, K. Konstantinov, and H. K. Liu, "A highly ordered titania nanotube array as a supercapacitor electrode", *Physical Chemistry Chemical Physics*, in press.
2. M. Salari, K. Konstantinov, and H. K. Liu, "Enhancement of the capacitance in TiO<sub>2</sub> nanotubes through controlled introduction of oxygen vacancies", *Journal of Materials Chemistry*, in press.
3. S. H. Aboutalebi, A. T. Chidembo, K. Konstantinov, D. Wexler, H. K. Liu, and S. X. Dou, "Comparison of GO, GO/MWCNTs composite and MWCNTs as potential electrode materials for supercapacitors", *Energy & Environmental Science*, in press.

### New directions to miniaturized power sources: integrated all-solid-state rechargeable batteries

<b>Funded:</b>	2010 2011 2012 2013 2014
<b>Project ID:</b>	DP1094261
<b>Chief</b>	Z. P. Guo, Z. Chen
<b>Investigators:</b>	
<b>Partner</b>	J. Dahn, J. Chen
<b>Investigators:</b>	

#### PROGRESS MADE IN 2010

Free-standing and flexible V<sub>2</sub>O<sub>5</sub> films have been prepared by filtration of ultra-long nanowires synthesised via the hydrothermal technique. In order to improve the conductivity of the films, multiwalled carbon nanotubes (MWCNTs) were added to the V<sub>2</sub>O<sub>5</sub> nanowires to form an integrated web-like structure. The possible use of these films as cathode for lithium ion batteries

was also investigated. The free-standing and flexible film electrodes exhibited good rate capability and excellent cycling performance, with capacity of 140 mAh/g, even after 50 cycles at 1.7 C in the voltage range of 2.5-4.0 V. The superior reversible lithium storage capability can be attributed to the fully reversible phase transitions of  $-V_2O_5$  through to  $\delta$ -Li  $V_2O_5$ , good lithium diffusion in  $V_2O_5$ , and increased electronic conductivity and electrolyte diffusion from the incorporated MWCNT web.

SnSb/graphene porous three dimensional (3-D) composite with dual buffering capability was prepared by an in situ chemical reduction of  $SnCl_2$ ,  $SbCl_3$ , and graphene oxide prepared using a modified Hummers' method. Field emission scanning electron microscope and transmission electron microscope images shows that the SnSb nanoparticles were distributed homogenously across the surface of the graphene sheets, and some were

also found trapped in the corrugated graphene structure. The electrochemical performances of the SnSb/graphene composite were investigated by cyclic voltammetry and galvanostatic charge/discharge testing. The SnSb/graphene composite delivered 688 mAh/g at the 2nd cycle (compared to a calculated theoretical value of 768 mAh/g) and shows good capacity retention of 420 mAh/g after 100 cycles. A reaction model to explain the dual buffering effects of SnSb/graphene composite as anode material for lithium insertion and extraction has been proposed.

We have also synthesised heterogeneous ZnS HUHNs on a large scale by using a controlled stepwise method without the use of sacrificial templates for the first time. The novel ZnS nanostructures consist of a cubic zinc-blende (ZnS) hollow sphere surrounded by hexagonal wurtzite (ZnS) nanowire arrays. Due to the two-phase and the high surface-to-volume ratio, such novel

heterogeneous ZnS HUHNs show greatly unique properties compared to commercial ZnS powders or as-synthesised single-phase ZnS nanobelts.

## PUBLICATIONS

1. K. H. Seng, Z. P. Guo, Z. X. Chen, and H.K. Liu, "SnSb/graphene nanocomposites as anode materials for lithium ion batteries", *Advanced Science Letters* 4, 18 (2011).
2. K. H. Seng, J. Liu, Z. P. Guo, Z. X. Chen, D. Z. Jia, and H. K. Liu, "Free-standing  $V_2O_5$  electrode for flexible lithium ion batteries", *Electrochemistry Communications*, in press (accepted on 08/12/2010).
3. J. Liu, Z. P. Guo, W. J. Wang, Q. S. Huang, K. X. Zhu, and X. L. Chen, "Heterogeneous ZnS hollow urchin-like hierarchical nanostructures", *Nanoscale*, in press (accepted on 19 Jan. 2011).

## Future Fellowship

### New directions to miniaturized power sources: integrated all-solid-state rechargeable batteries

<b>Funded:</b>	2009 2010 2011 2012 2013
<b>Project ID:</b>	FT0990391
<b>Chief Investigators:</b>	Z. X. Cheng

#### PROGRESS MADE IN 2010

Novel multiferroic materials for spintronics application and manipulation of spin: We proposed a new way to enhance the magnetic moment of the famous multiferroic material  $BiFeO_3$ . The basic idea is to doped transition metals to create local ferromagnetic structure, while keeping the spiral magnetic structure of  $BiFeO_3$  [1].

A new multiferroic system with potential for spin manipulation was discovered, rare chromates. Thin films were fabricated and their band gap, polarisation, and magnetism were studied [2].

A novel Arrhenius structured single-ferroic thin film was fabricated and studied for the first time, which shows good ferroelectric hysteresis and fatigue resistance behavior [3].

Multiferroic rare earth manganites have been studied with an emphasis on their structure, magnetic properties, and magnetoelectric coupling effects. We found that Cu doping into  $ErMnO_3$  can significantly enhance the magnetic moment by modifying the magnetic structure. We also found a very large magnetocapacitance effect, in which the capacitance was enhanced by an applied magnetic field. The mechanism

behind this phenomenon was studied by complex impedance techniques. It was found that the magnetocapacitance effect is caused by the reduction in complex resistance in magnetic field. This mechanism might account for most of the magnetocapacitance effects observed and reported in various materials so far. This was work selected as a research highlight on the website of IOP Asia-Pacific [4].

The double perovskite structured multiferroic material  $Bi_2FeMnO_6$  was fabricated by the electrospray method for the first time. We have found that the material displays several magnetic transitions from low to high temperatures, which are assigned to the ordering of Mn-Mn, Mn-Fe, and Fe-Fe. This material has been very difficult to fabricate previously [5].

We have fabricated the colossal magnetoresistance material  $\text{La}_{2/3}\text{Ca}_{1/3}\text{MnO}_3$  on a piezoelectric  $\text{BaTiO}_3$  single crystal substrate. The magnetic and transport properties of  $\text{La}_{2/3}\text{Ca}_{1/3}\text{MnO}_3$  film were modulated using structure distortion at phase transitions of the  $\text{BaTiO}_3$  substrate. Anomalies of the magnetic moment and a sharp drop in the resistance of the film are observed in zero magnetic field at the  $\text{BaTiO}_3$  phase transition temperatures. However, the anomalies for both resistance and magnetisation are eliminated by high magnetic field. This phenomenon indicates the existence of a strong electron-phonon interaction in  $\text{La}_{2/3}\text{Ca}_{1/3}\text{MnO}_3$ , and magnetic field can produce a larger structural distortion in it than what is produced by

clamping effects at the substrate structure phase transition. This work demonstrated that the magnetisation or spin can be modulated by the strain caused by the substrate structure distortion, revealing the potential for applying an electrical field on a piezoelectric substrate to control the strain and thus manipulating the magnetization in applications.

#### PUBLICATIONS

1. Z. X. Cheng et al., "A way to enhance the magnetic moment of multiferroic bismuth ferrite", *Journal of Physics D: Applied Physics* 43, 242001 (2010).
2. Z. X. Cheng et al., "A novel multiferroic system: Rare earth chromates", *Journal of Applied Physics* 107, 09D905 (2010).
3. Z. X. Cheng et al., "Lead-free potassium bismuth titanate thin film with complex Aurivillius layer structure", *Journal of Applied Physics* 107, 084105 (2010).
4. P. Liu, Z. X. Cheng et al., "Enhanced magnetic moment in  $\text{ErMnO}_3$  by copper doping and negative magnetocapacitance effect", *Journal of Physics D: Applied Physics* 43, 325002 (2010).
5. Y. Du, Z. X. Cheng, S. X. Dou, and X. L. Wang, "Magnetic properties of a novel multiferroic material:  $\text{Bi}_2\text{FeMnO}_8$  with a double-perovskite structure", *Applied Physics Letters* 97, 122502 (2010).

## ARC Linkage Projects

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

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

#### PROGRESS MADE IN 2010

The project aim is to develop novel technologies for new superconducting current leads, carrying large channels of digital information with minor attenuation and ultra-low thermal conductivity for high-sensitivity, low-noise superconductive cryogenic electronics. The successful outcome will be the realisation of multi-line heat-switches based on multilayer

thin/thick-film techniques, which would minimise heat generation and its transfer to cryoelectronic components.

In the previous year, an absolutely novel and unique design of the long heater with reciprocating movement for pulsed laser deposition of long YBCO film on flexible substrates has been implemented. Excellent superconducting properties of YBCO films have been obtained over the entire length of the 8cm long YBCO films. However, the heater setup had quite short life span due as the halogen lamps employed for heating could not withstand heater movement. To eliminate this problem, a new design of the heater has been proposed and almost completed based on long resistive elements, which is expected to provide longer life span of the heating elements, more productive process and reproducing results.

New low temperature experimental setup allowing us to measure superconducting properties of 8cm long films has been implemented and is successfully utilised.

Moreover, surface resistance of large multi and mono-layered films have been measured at 77 K, showing surface resistance lower on the multilayered film which is preliminary attributed to its smoother surface.

Optical lithography procedure of the long and short samples with feature dimensions of up to 8cm long and 1 micron wide has been setup and optimised for superconducting strip lines. As a result, we have been able to create a Josephson junction for the first time in our group at the ISEM. Moreover, multilayered approach to YBCO-based Josephson junction manufacture has also been introduced for the first time. The multilayered approach turned out to provide superior junction properties to the junctions based on monolayered YBCO films. Properties of monolayer  $\text{YBa}_2\text{Cu}_3\text{O}_7$  (YBCO) and multilayer YBCO/NdBCO/YBCO junctions of similar thickness grown by pulsed-laser deposition on MgO (100) substrates has

been analysed and compared. The influence of the multilayered structure on junction behaviour, structure and properties has been investigated. Results have been published.

High temperature superconducting  $\text{YBa}_2\text{Cu}_3\text{O}_7$  films have also been prepared deposited on top of single crystal substrates and metallic templates. Films have been investigated in order to determine the influence of microstructural peculiarities on the critical current density. It has been found that there is an inherent mechanism limiting the superconductive current flow in YBCO film deposited on metallic templates. This limiting mechanism is associated with the film architecture, fabrication procedure and following low temperature usage, which promotes more pronounced grain boundary network of the films with reduced superconducting properties. These results have been published.

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

## PUBLICATIONS

1. O. V. Shcherbakova, A. V. Pan, S. Fedoseev, S. X. Dou, et al., "Multilayered approach to step-edge Josephson junctions", *Materials Science Forum* 654-656, 1836 (2010).
2. O. V. Shcherbakova, A. V. Pan, S. X. Dou, R. Nigam and D. Wexler, "Nanocoating of particles for optimal doping and universal enhancement of current-carrying ability in "organic"  $\text{MgB}_{2-x}\text{C}_x$  superconductors", *Journal of Applied Physics* 107, 09E147 (2010).
3. S. V. Pysarenko, A. V. Pan, S. X. Dou, "Constraints of super-current flow in YBCO coated conductors", *Materials Science Forum* 654-656, 1704 (2010).

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

<b>Funded:</b>	2008 2009 2010
<b>Project ID:</b>	LP0882282
<b>Chief</b>	C. Zhang, X. L.
<b>Investigators:</b>	Wang, G. X. Wang
<b>Partner</b>	T. Toyoda
<b>Investigator:</b>	

### PROGRESS MADE IN 2010

The project has been terminated after mutual agreement between the ARC and Industry Partner.

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

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

### PROGRESS MADE IN 2010

Tin-manganese oxide film with three-dimensional (3D) reticular structure has been prepared by electrostatic spray deposition (ESD). X-ray diffraction (XRD) and transmission electron microscopy (TEM) indicate that the film is amorphous. X-ray-photoemission spectroscopy (XPS) demonstrates that the 3D grid is composed of tin-manganese oxide. As an anode electrode for the lithium ion battery, the tin-manganese oxide film has 1188.3 mAh/g of initial discharge capacity and very good capacity retention of 656.2 mAh/g up to the

30th cycle. Such a composite film can be used as an anode for lithium ion batteries with higher energy densities.

Nanosized carbon-coated  $\text{Li}_{1-3x}\text{La}_x\text{FePO}_4$  composites were synthesised using a fast, easy, microwave assisted, room-temperature, solid-state method. A lanthanum precursor was used to improve the electronic conductivity of  $\text{LiFePO}_4$ . The particle structure of the as-synthesised samples was observed using transmission electron microscopy. The results indicated that a uniform and continuous carbon layer was formed on the surface of  $\text{Li}_{1-3x}\text{La}_x\text{FePO}_4$  particles. Electrochemical techniques, such as cyclic voltammetry, charge/discharge test, and electrochemical impedance spectroscopy were used to investigate the electrochemical performance of the samples. The results of electrochemical measurements revealed that the carbon coating and lanthanum doping provided an initial discharge capacity of 145 mA h/g with excellent rate capacity and long cycling stability. These advantages, coupled with the low cost, the high thermal stability, and the environmental friendliness of the raw materials, render  $\text{Li}_{1-3x}\text{La}_x\text{FePO}_4$  composites attractive for practical and large-scale applications.

Cobalt-doped tungsten disulfide nanorods were synthesised by an approach involving exfoliation, intercalation, and the hydrothermal process, using commercial  $\text{WS}_2$  powder as the precursor and n-butyllithium as the exfoliating reagent. XRD results indicate that the crystal phase of the sample is 2H- $\text{WS}_2$ . TEM images show that the sample consists of bamboo-like nanorods with a diameter of around 20 nm and a length of about 200 nm. The Co-doped  $\text{WS}_2$  nanorods exhibit the reversible capacity of 568 mAh  $\text{g}^{-1}$  in a voltage range of 0.01-3.0 V versus  $\text{Li}/\text{Li}^+$ . As an electrode material for the lithium battery, the Co-

doped  $WS_2$  nanorods show enhanced charge capacity and cycling stability compared with the raw  $WS_2$  powder.

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2. S. Q. Wang, G. D. Du, L. Li, C. Q. Feng, and Z. P. Guo, "Synthesis and characterization of cobalt-doped  $WS_2$  nanorods for lithium ion battery applications", *Nanoscale Research Letters* 8, 1301 (2010).
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## Magnesium diboride superconductor magnets for applications

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

### PROGRESS MADE IN 2010

Comparative study of mono and multi-filament  $MgB_2$  wires with different boron powders and malic acid addition: We evaluated the effects of different boron (B) powders and of malic acid ( $C_4H_6O_5$ ) addition on the critical current density ( $J_c$ ) of mono and multi-filament  $MgB_2$  wires. We found that  $J_c$  of the wires made from the amorphous B showed the best performance. Low sintering processing keeps the grain size small, which leads to strong flux pinning. From transmission electron microscopy (TEM) observations, we confirmed that the crystalline B powders supplied by SMI and Tangshan had a  $\bar{r}$ -rhombohedral structure as a main phase. These two powders also had numerous defects, such as twin and stacking faults inside the powder particles. However, these defects are not enough to promote the full reaction between magnesium (Mg) and B crystalline powder when sintered at low temperatures, and brings about low  $J_c$  values. Even though the morphologies of the two crystalline B powders appeared somewhat different,  $J_c$  for the two wires had similar quantitative values.

For the malic acid doped wires,  $J_c$  of the wire made from the amorphous B was estimated to be above  $100\,000\text{ A cm}^{-2}$  at 6 T and 4.2 K. This value is comparable to the low temperature superconductor Nb-Ti. In addition, the  $J_c$  was  $25\,000\text{ A cm}^{-2}$  at 10 T

and 4.2 K. This performance is the best  $J_c$  reported so far in in situ processed  $MgB_2$  wires. At 20 K, enhanced performance of  $J_c$  by malic acid doping is much higher than that of the pure  $MgB_2$  wire,  $J_c$  at 5 T and 20 K was estimated to be  $13\,000\text{ A cm}^{-2}$ .

Effect of Mg/B ratio and SiC doping: we systematically studied the effects of the nominal Mg/B mixing ratio  $x:2$  on the superconductivity, Raman spectra, current transport properties, and flux pinning mechanism in  $MgB_2$  with 10 wt.% SiC doping.  $x$  was varied from 1 to 1.2. It has been seen that compared to  $MgB_2$  without doping, the SiC-doped sample with the stoichiometric nominal Mg/B ratio 1:2 has significantly increased  $J_c$  at high fields. However, its self-field  $J_c$  and  $T_c$  were depressed. Through the optimisation of the nominal Mg/B ratio, we found that the sample with  $x=1.15$  exhibited the best  $J_c$  performance for all the fields 0–8.5 T, including the self-field, and its  $T_c$  was higher than for the sample with  $x=1$ . The enhancement of  $J_c$  is attributed to the improved connectivity and the increased disorder, both of which were achieved by the optimization of the Mg/B ratio. The optimized Mg/B ratio 1.15:2 also diminished the interband scattering caused by the Mg or B vacancies and in turn, increased  $T_c$ .

Superconducting transition width under magnetic field in  $MgB_2$  polycrystalline samples: A systematic study on the superconducting transition width as a function of the applied magnetic field was performed in polycrystalline  $MgB_2$ . A quantitative, yet universal relation between the two parameters was observed in all of the ceramics. It was found that the width decreases linearly with decreasing field in pure  $MgB_2$  samples. Whereas, samples with boron and/or Mg atoms partially replaced by other elements show this linear relation in the temperature range below 0.7–0.8 of the superconducting transition

temperature corresponding to a field of about 2 T, at temperatures higher than this range, an abnormal upturn in the width was found. This upturn is ascribed to multiple superconducting transitions. A core-shell model is proposed to describe the multiple transitions.

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1. S. R. Ghorbani et al., "Strong competition between the  $I$  and  $T_c$  flux pinning mechanisms in  $MgB_2$  doped with carbon containing compounds", *Journal of Applied Physics* 107, 113921 (2010).
2. J. H. Kim et al, "Comparative study of mono- and multi-filament  $MgB_2$  wires with different boron powders and malic acid addition", *Superconductor Science & Technology* 23, 075014 (2010).
3. C. C. Wang et al., "Superconducting transition width under magnetic field in  $MgB_2$  polycrystalline samples", *Journal of Applied Physics* 108, 093907 (2010).

## Design, build and test a fault current limiter employing magnesium diboride ( $MgB_2$ ) superconducting coils

<b>Funded:</b>	2010 2011 2012
<b>Project ID:</b>	LP100100440
<b>Chief</b>	S. X. Dou, J. Horvat,
<b>Investigators:</b>	X. Xu, J. W. Moscrop

## PROGRESS MADE IN 2010

Personnel: X. Xu started his fellowship under the project. Two PhD students are contributing to project. K. W. See is supported by UPA scholarship and his contribution is in measuring AC loss and transport properties of the  $MgB_2$  wire that will be used in superconducting coil. J. Knott

is working on the simulation of thermal properties of the superconducting coil and associated cooling system.

Equipment: System for measuring the transport properties of  $MgB_2$  wires between 20 and 30K was set-up. It is capable of measuring high critical current (up to 200A) in dc mode. Additional dc power supply has been ordered to enable the use of dc currents up to 400A. A transformer for a 12kW power AC source has been ordered, to enable the use of pulsed current with variable duration up to 800A. If the heating due to dc current proves to be too high, pulsed current of different duration will be used and measured critical current extrapolated to its dc value.

Progress: Search for  $MgB_2$  wire suitable for the superconducting coil showed that the only option will be the wire made by Columbus. Other manufacturers that are producing  $MgB_2$  wire of higher critical current are not willing to sell it for this project for intellectual property reasons. Sample lengths of Columbus wires were acquired and its transport properties tested. Experimental set-up had to be developed that would enable testing this wire at temperatures between 20 and 30K, without submerging it into cryogenic fluid. Such configuration will be used in fault current limiter. A calorimetric method was devised for measurements of ac losses in superimposed AC and DC fields. These losses will affect the thermal design of the superconducting coil. Main parameters of this wire that will be needed for the coil design are currently being measured for the sample wires provided by Columbus.

Numerical code for thermal design of superconducting coil system is being developed, pending the experimental results for the Columbus wire samples. Iron core

and copper coils are being designed so that they suit the requirements (size, field) of the superconducting magnet.

## PUBLICATIONS

1. K. W. See, C. D. Cook, S. X. Dou, "Innovative calorimetric AC loss measurement of HTSC for power applications", *IEEE Transactions on Applied Superconductivity* 3MA-04, R1 (Accepted 12/2010), *Applied Superconductivity Conference* 2010.
2. X. Xu, W. X. Li, Y. Zhang, K. S. B. De Silva, J. H. Kim, S. Choi, "The effects of graphene doping on the in-field  $J_c$  of  $MgB_2$  wires", *Journal of Nanoscience and Nanotechnology*, P-P-07, (Accepted 12/2010), *IUMRS-ICEM* 2010.
3. X. Xu, S. X. Dou, X. L. Wang, J. H. Kim, J. A. Stride, M. Choucair, W. K. Yeoh, R. K. Zheng, and S. P. Ringer, "Graphene doping to enhance flux pinning and supercurrent carrying ability in magnesium diboride superconductor", *Superconductor Science & Technology* 23, 085003 (2010).
4. W. K. Yeoh, R. K. Zheng, S. P. Ringer, W. X. Li, X. Xu, S. X. Dou, S. K. Chen and J. L. MacManus-Driscoll, "Evaluation of carbon incorporation and strain of doped  $MgB_2$  superconductor by Raman spectroscopy", *Scripta Materialia* 64, 323 (2011).

## Room temperature rechargeable sulphur batteries

<b>Funded:</b>	2010 2011 2012
<b>Project ID:</b>	LP100100802
<b>Chief Investigators:</b>	J. Z. Wang, H. K. Liu, K. Konstantinov
<b>Partner Investigators:</b>	Z. X. Wang

### PROGRESS MADE IN 2010

Sulphur-graphene (S-GNS) composites have been synthesised by heating a mixture of graphene nanosheets and elemental sulphur. According to field emission electron microscopy, scanning electron microscopy with energy dispersive X-ray mapping, Raman spectroscopy, and thermogravimetric analysis, sulphur particles were uniformly coated onto the surface of the graphene nanosheets. The electrochemical results show that the sulfur-graphene nanosheet composite significantly improved the electrical conductivity, the capacity, and the cycle stability in a lithium cell compared with the bare sulphur electrode. A paper entitled "Sulphur-Graphene Composite for Rechargeable Lithium Batteries" has been accepted by *Journal of Power Sources* (online available, DOI: 10.1016/j.jpowsour.2010.09.106).

CuS nanoparticles, including nanoflakes, microspheres composed of nanoflakes microflowers, and nanowires have been selectively synthesised by a facile hydrothermal method using  $\text{CuSO}_4$  and thiourea as precursors under different conditions. The morphology of CuS particles were affected by the following synthetic parameters: temperature, time, surfactant, pH value, solvent, and concentration of the two precursors. The synthesised CuS nanomaterials were characterized by X-ray diffraction, Brunauer-Emmett-Teller  $\text{N}_2$  adsorption, scanning electron

microscopy,) and energy-dispersive X-ray spectroscopy. The electrochemical tests, including constant current charge-discharge and cyclic voltammetry, show the specific capacities of the different morphologies, as well as their cycling stability. Due to their nano-/micro-particle size and compact structure, the nanowires and microspheres present relatively higher initial discharge capacity of  $262 \text{ mAh g}^{-1}$  and  $258 \text{ mAh g}^{-1}$ , respectively, among these four CuS nanomaterials, while the microspheres show the best stability over 50 cycles. The nanowire electrode shows the best rate capability, with around  $58 \text{ mAh g}^{-1}$  at 1 C. The dissolution of CuS in electrolyte is still a big issue for capacity fading, and a further protective coating layer on the surface of the CuS nanomaterials or additives in the electrolyte may be needed to improve the performance.

# Current and Ongoing Research Projects

## ARC Centre of Excellence

### Nano-materials for energy storage

<b>Years funded:</b>	2006	2007	2008	2009	2010
<b>Amount funded:</b>	\$230,000	\$230,000	\$230,000	\$230,000	\$230,000
<b>Project ID:</b>	CE0561616				
<b>Chief Investigator:</b>	H. K. Liu				
<b>Research Fellow:</b>	J. Z. Wang				
<b>Postgraduate Students:</b>	S. L. Chou, MD. M. Rahman, N. Idris, C. Zhong, L. Neorochim, S. Li, I. Sultana				

## ARC Discovery Projects

### Current limiting mechanisms in magnesium diboride superconductors

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

**Project Summary:** Numerous important applications have already been identified for MgB<sub>2</sub> wire: power transmission cables, fault current limiters, transformers and magnets for motors and generators, as well as MRI. The significant increase in current carrying capacity of one order of magnitude expected to result from the proposed program will enable MgB<sub>2</sub> to replace presently existing low-temperature superconductors (LTS) and expensive high-temperature superconductors (HTS) in numerous important applications. MgB<sub>2</sub> technology, coupled with renewable energy sources, has the potential to provide a long term solution to the energy crisis and global warming threat.

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

<b>Years Funded:</b>	2008	2009	2010
	\$100,000	\$100,000	\$100,000
<b>Total Funding:</b>	\$300,000		
<b>Project ID:</b>	DP0878611		
<b>Chief Investigator:</b>	Z. P. Guo		

**Project Summary:** This project represents a significant scientific and economic advance for Australia because:

1. it is likely to create advanced energy storage and conversion devices, with excellent working efficiency and kinetics, which will induce dramatic improvements to our environment;
2. the project will establish local expertise and scientific know-how on electrochemical energy storage and conversion systems, which will place Australia at the forefront of this important area of lithium ion battery and PEM fuel cells; and
3. relevant Australian enterprises in electric vehicle and portable device manufacturing will reap the benefits of these discoveries.

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

<b>Years Funded:</b>	2008	2009	2010
	\$35,000	\$35,000	\$35,000
<b>Total Funding:</b>	\$105,000		
<b>Project ID:</b>	DP0879714		
<b>Chief Investigator:</b>	G. Peleckis		

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

## Fabrication of high quality MgB<sub>2</sub> superconductor

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

**Project Summary:** Superconductors are electrical resistance free materials. They have great potential for power applications. Nowadays, superconductors have been used in applications such as Magnetic Resonance Imaging and other R&D equipment. This project deals with newly discovered MgB<sub>2</sub> superconductor. The process outlined in this project will produce MgB<sub>2</sub> superconductor with better superconducting properties. The application of MgB<sub>2</sub> superconductor will save energy, and enhance the performance of existing electrical devices such as magnet and power line.

## Giant magnetocaloric materials and room temperature refrigeration

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

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

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

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

**Project Summary:** Energy systems of the future must be cleaner and much more efficient, flexible, and reliable to meet the growing global demand for energy. A hydrogen economy offers a potential solution to satisfying the global energy requirements while reducing carbon dioxide and other greenhouse gas emissions and improving energy security. The enhanced hydrogen storage materials to be investigated will have higher hydrogen storage capacity, which can have applications in a variety of areas, including the storage and transport of hydrogen, fuel cells and electric automobiles.

## Novel graphene nanostructures: modelling, synthesis, fabrication and characterization

<b>Years Funded:</b>	2008	2009	2010
	\$150,000	\$145,000	\$145,000
<b>Total Funding:</b>	\$440,000		
<b>Project ID:</b>	DP0879151		
<b>Chief Investigators:</b>	C. Zhang, D. Li		
<b>Partner Investigators:</b>	F. Liu, R. B. Kane, Y. Jiang		

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

Tailoring superconducting hybrid multilayered film systems for electric and electronic applications

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

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

## Frustrated magnets: a new platform for multiferroic materials

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

**Project Summary:** Ferroelectric materials with simultaneous ferroelectricity and ferromagnetism are one of the most important new emerging fields in the materials science and condensed matter physics communities. Novel magneto-electronic devices based on new multiferroic materials will open up a huge market for these devices, which are expected to have a huge impact on modern science and daily life. The purpose of this project is to make Australia one of the leading countries in this field and to work with colleagues in Australia and around the world to move this field forward for mutual benefit.

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

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

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

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

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

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

## New directions to miniaturised power sources: integrated all-solid-state rechargeable batteries

<b>Years Funded:</b>	2010	2011	2012	2013	2014
	\$135,000	\$145,000	\$140,000	\$160,000	\$120,000
<b>Total Funding:</b>	\$700,000				
<b>Project ID:</b>	DP1094261				
<b>Chief Investigators:</b>	Z. P. Guo, Z. Chen				
<b>Partner Investigator:</b>	J. Dahn, J. Chen				

**Project Summary:** This project will lead to the development of safe integrated all-solid-state miniaturised lithium ion batteries for small autonomous devices, such as implantable medical devices, hearing aids, small autonomous devices with sensing and actuation, and for communications and rapid chemical/biological analysis. This will make a significant contribution to the nation in the areas of science, technology, health, and the economy. The development of new scientific knowledge related to this project will place Australia at the forefront of an emerging domain of research. The project will also provide excellent training for postgraduate students and young researchers to develop their skills in chemistry, materials science and battery technology.

## Directed assembly and photoelectric properties of core-shell nanowire networks of PbSe-TiO<sub>2</sub> heterostructures for high efficiency low-cost solar cells

<b>Years Funded:</b>	2010	2011	2012
	\$100,000	\$95,000	\$105,000
<b>Total Funding:</b>	\$300,000		
<b>Project ID:</b>	DP1096546		
<b>Chief Investigators:</b>	J. H. Kim, Y. Zhao, X. Zhu, Z. Sun		
<b>Partner Investigator:</b>	Y. Kang, G. Ramanath		

**Project Summary:** The proposed program is aimed at studying numerous fundamental properties and phenomena of photo-electrochemical cells that have an important impact on environmentally friendly solutions to energy problems. Specifically, solar cells have a significant role in energy markets and in lessening CO<sub>2</sub> emissions and other environmental impacts. Solar cell technology, coupled with renewable energy sources, has the potential to provide a long-term solution to the energy crisis and the global warming threat. In addition, the strong team to be assembled will reach a leading position in this area of cutting edge technology. The outcomes will benefit Australian industries.

## Advanced nanostructured ceramic composites for ultracapacitors

<b>Years Funded:</b>	2010	2011	2012
	\$90,000	\$90,000	\$90,000
<b>Total Funding:</b>	\$270,000		
<b>Project ID:</b>	DP1093952		
<b>Chief Investigators:</b>	K. K. Konstantinov, H. K. Liu, A. Calka, D. Wexler		

**Project Summary:** The global climate changes and the related disastrous events such as heat flows, bushfires, and flooding will endanger Australian population and our natural environment. The implementation of effective devices and technologies to reduce our carbon footprint is a priority task. The project addresses the issue by development of new ultracapacitor materials for next generation green energy storage devices through engineering and implementation of advanced nanoceramics and nanocomposites created by innovative nanotechnologies. The project will also contribute to other national research priorities such as materials and frontier technologies, reduction of atmospheric pollution, and decrease in the energy dependence of our country on oil.

## Materials science and superconductivity in the new Fe-based high temperature superconductors

<b>Years Funded:</b>	2010	2011	2012	2013
	\$155,000	\$150,000	\$150,000	\$100,000
<b>Total Funding:</b>	\$555,000			
<b>Project ID:</b>	DP1094073			
<b>Chief Investigators:</b>	X. L. Wang, G. Peleckis, D. Chen			
<b>Partner Investigator:</b>	H. Hosono, X. Chen, K. H. Muller, E. Muromachi, A. J. Studer			

**Project Summary:** Novel superconducting materials with high superconducting transition temperature and upper critical field are one of the most important research fields in the community of materials science and condensed matter physics. Any significant breakthrough in Fe-based superconductors will result in exotic physics and possible novel superconducting electronic devices, and will have the potential for ground-breaking research. The purpose of this project is to bring Australia to the forefront of this field and to work with world leading researchers within Australia and worldwide to make advancements in this field.

## ARC Future Fellowship

### Manipulation of spin by electric field

<b>Years Funded:</b>	2009	2010	2011	2012	2013
	\$86,000	\$172,000	\$172,000	\$172,000	\$86,000
<b>Total Funding:</b>	\$688,000				
<b>Project ID:</b>	FT0990391				
<b>Chief Investigators:</b>	Z. X. Cheng				

**Project Summary:** Spin manipulation is one of the most challenging topics in the new emerging spintronics technology. This project will develop a novel solution for the problem of spin manipulation and falls into the National Research Priority: Frontier Technologies for Building and Transforming Australian Industries. This project will provide training for postgraduate students and develop patentable science and technologies. The successful accomplishment of this project will consolidate the knowledge and technology background that is needed for Australia to develop the next generation of spin-base electronics. In the long term, spin-based electronics with high efficiency and very low energy consumption will benefit the Australian manufacturing industry.

## ARC Linkage Projects

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

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

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

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

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

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

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

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

**Project Summary:** This project represents a significant scientific and economic development for advanced, high performing energy storage devices with a focus on safety that will provide enormous benefits for the environment. An added advantage will be the establishment of local and national expertise in the area of electrochemical energy storage systems that will place Australia at the forefront of lithium ion battery research and development. Flow-on benefits will also be created for Australian organisations involved in the manufacturing of electric vehicles and portable devices.

## Magnesium diboride superconductor magnets for applications

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

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

## Design, build and test a fault current limiter employing magnesium diboride (MgB<sub>2</sub>) superconducting coils

<b>Year Funded:</b>	2010	2011	2012
	\$195,000	\$190,000	\$195,000
<b>Total Funding:</b>	\$580,000		
<b>Project ID:</b>	LP100100440		
<b>Chief Investigators:</b>	S. X. Dou, J. Horvat, X. Xu, J. W. Moscrop		
<b>Industry Partner:</b>	Zenergy Power Pty Ltd.		

**Project Summary:** Recent occurrences of blackouts around the world caused immeasurable damage to electrical network hardware in the range of \$10 million; however, the losses from an unavailable network are much more. The CIs and Zenergy Power Pty Ltd (formerly Australian Superconductors) have been developing saturated core fault current limiters (FCL) since 1999. The first saturated core fault current limiter employing the Australian entity's technology was installed in California. The aim of this proposal is to extend this technology to demonstrate next generation FCL using newly developed superconductor magnesium diboride (MgB<sub>2</sub>) wire which is cheaper and easier to manufacture than high temperature superconductors and the CI's group hold strong IP on nano-scale chemically doped MgB<sub>2</sub> wires.

## Room temperature rechargeable sulphur batteries

<b>Year Funded:</b>	2010	2011	2012
	\$70,000	\$58,000	\$100,000
<b>Total Funding:</b>	\$228,000		
<b>Project ID:</b>	LP100100802		
<b>Chief Investigators:</b>	J. Z. Wang, H. K. Liu, K. K. Konstantinov		
<b>Partner Investigator:</b>	Z. X. Wang		
<b>Industry Partner:</b>	DLG Battery Co Ltd, Nipress Tbk Pt		

**Project Summary:** The project will lead to the development of low cost sulphur rechargeable batteries for electric vehicles and hybrid electric vehicles and will contribute to the national priority goal of reducing and capturing emissions in transport to improve our environment. The project will take the incentive in establishing a leading national position in the development of low cost energy storage technology. The partner organisation, Nipress, has close connection to Australia. The company has imported raw materials (metal lead, 8000 tons) from Australia every year. The success of sulphur batteries technology will increase the opportunity of Nipress using more Australian raw materials.

## Linkage International Awards

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

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

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

### Mechanism and enhancement of supercurrent carrying ability in magnesium diboride superconductor

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

**Project Summary:** The newly discovered MgB<sub>2</sub> superconductor has great potential to replace the existing conventional superconductors for uses in various medical and industrial applications. This project brings together two world leading groups with complementary expertise to develop a fundamental understanding of the factors controlling MgB<sub>2</sub> performance and to find effective ways to significantly improve its supercurrent carrying capabilities for practical applications. The outcome of this project will be of benefit to both countries and will lead to many practical applications such as transformers, rotors and transmission cables, as well as magnetic resonance imaging without using liquid helium, reducing greenhouse gas emissions and global warming.

## Other Non-ARC Grants

### High performance nanomaterials for thermionics and thermoelectrics applications

<b>Funding Scheme:</b>	DIISR International Science Linkage project		
<b>Year Funded:</b>	2008	2009	2010
	\$135,000	\$85,000	\$73,000
<b>Total Funding:</b>	\$293,000		
<b>Chief Investigators:</b>	C. Zhang, R. A. Lewis, X. L. Wang, D. Li		

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

### Development of terahertz emitters based on electronic and hybrid spintronic materials

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

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

## URC Small Grants & ARC Near-Miss Grants 2010

### **Doped BiFeO<sub>3</sub> thin film on piezoelectric substrates for robust room temperature magnetocaloric coupling**

**Total Funding:** \$13,000

**Chief Investigators:** Z. X. Cheng

### **Design and synthesis of ammonia-borane complexes with high hydrogen capacity**

**Total Funding:** \$10,000

**Chief Investigators:** X. B. Yu

### **Surface modification of titanium and titanium alloys for biomedical device applications**

**Total Funding:** \$9,000

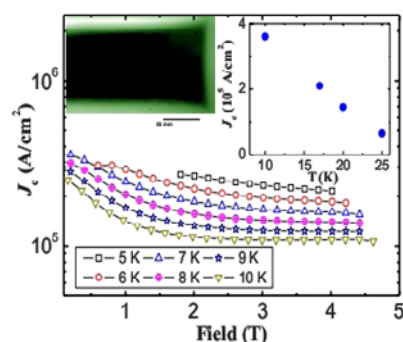
**Chief Investigators:** Y. Zhao

### **Application of functionalised nanoceramics for protection from radiation and oxidative stress related disorders**

**Total Funding:** \$8,000

**Chief Investigators:** K. Konstantinov

# Selected Abstracts

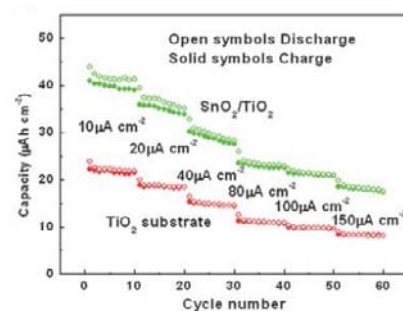
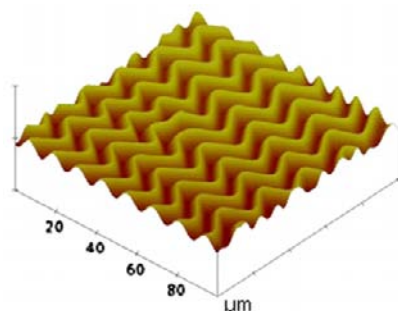


## Very strong intrinsic flux pinning and vortex avalanches in (Ba, K)Fe<sub>2</sub>As<sub>2</sub> superconducting single crystals

We report that the (Ba, K)Fe<sub>2</sub>As<sub>2</sub> crystal with  $T_c=32$  K shows a pinning potential,  $U_0$ , as high as  $10^4$  K, with  $U_0$  showing very little field dependence. The (Ba, K)Fe<sub>2</sub>As<sub>2</sub> single crystals become isotropic at low temperatures and high magnetic fields, resulting in a very rigid vortex lattice, even in fields very close to  $H_{c2}$ . The isotropic rigid vortices observed in the two-dimensional (2D) (Ba, K)Fe<sub>2</sub>As<sub>2</sub> distinguish this compound from 2D high- $T_c$  cuprate superconductors with 2D vortices. The vortex avalanches were also observed at low temperatures in the (Ba, K) Fe<sub>2</sub>As<sub>2</sub> crystal. It is proposed that it is the K substitution that induces both almost isotropic superconductivity and the very strong intrinsic pinning in the (Ba, K)Fe<sub>2</sub>As<sub>2</sub> crystal. (X .L. Wang et al., *Physical Review B* 82, 024525 (2010))

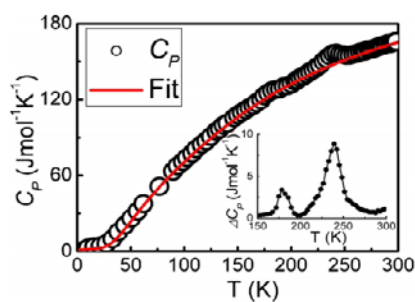
## Structural and morphological modification of PDMS thick film surfaces by ion implantation with the formation of strain-induced buckling domains

Elastomer films with three-dimensional features self-organized into coherent and semi-coherent buckling domains were created by implanting different species of metal ions and combinations thereof, using a metal evaporation ion Source, into quality polydimethylsiloxane films. As a result of the implantation process, functionalized discrete regions of strain-induced surface buckling were created, taking the forms of domains of parallel surface waves, semi-ordered regions and disordered regions. In addition, deep, strain-induced, V-shaped cracks were observed to penetrate well into the elastomer matrix. Characterization was via optical microscopy, X-ray diffraction, atomic force microscopy and high-resolution scanning electron microscopy (SEM) in the form of field emission SEM. It was found that controlling the localized strain by altering the metal ion species can control the frequency of the V-shaped cracks and the properties of the buckled areas. These observations and possible mechanisms for the formation of the cracks and domains are discussed in this paper. (B. R. Winton et al., *Acta Materialia* 58, 1861 (2010))



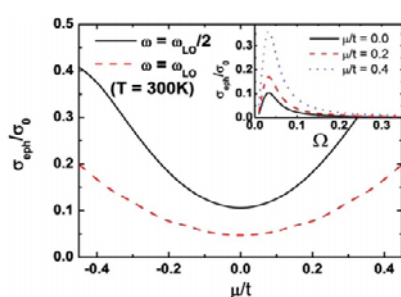
## SnO<sub>2</sub> nanocrystals on self-organized TiO<sub>2</sub> nanotube array as three-dimensional electrode for lithium ion microbatteries

Three-dimensional (3D) anodes have been prepared for lithium ion microbatteries by depositing SnO<sub>2</sub> nanocrystals into self-organized TiO<sub>2</sub> nanotube arrays through the solvothermal method, with the SnO<sub>2</sub> crystal size less than 5 nm. The 3D SnO<sub>2</sub>-TiO<sub>2</sub> anodes exhibit excellent electrochemical performance with good capacity retention of up to 70.8% over 100 cycles in the voltage range of 0.05–2.5 V. SnO<sub>2</sub> enhances the capacity to more than double that of bare TiO<sub>2</sub>, while TiO<sub>2</sub> nanotubes accommodate the volume changes of SnO<sub>2</sub> during charge/discharge cycling. The amount of SnO<sub>2</sub> loading can be controlled by varying the reaction time. The capacity of the 3D electrodes is controlled by the TiO<sub>2</sub> tube length as well as by the amount of SnO<sub>2</sub> loading. The maximum reversible capacity of the present samples can reach as high as about 300  $\mu\text{Ah cm}^{-2}$ . (G. D. Du et al., *Journal of Materials Chemistry* 20, 5689 (2010))



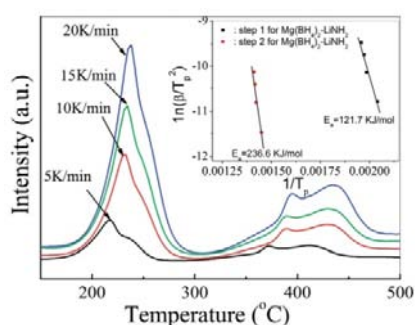
## Magnetic properties of $\text{Bi}_2\text{FeMnO}_6$ : A multiferroic material with double-perovskite structure

Single phase  $\text{Bi}_2\text{FeMnO}_6$  was synthesized on Si substrates by an electrospray method. Three peaks were observed in the temperature dependence of magnetization curve, which is attributed to the inhomogeneous distribution of  $\text{Fe}^{3+}$  and  $\text{Mn}^{3+}$ . The observed magnetic peaks at 150 K, 260 K, and 440 K correspond to orderings of the ferrimagnetic Fe-O-Mn, and antiferromagnetic Mn-O-Mn and Fe-O-Fe, respectively. Heat capacity measurements were carried out to confirm these magnetic transitions. The Debye temperature of  $\text{Bi}_2\text{FeMnO}_6$  is 339 K, calculated from Debye-Einstein fitting. (Y. Du et al., Applied Physics Letters 97, 122502 (2010))



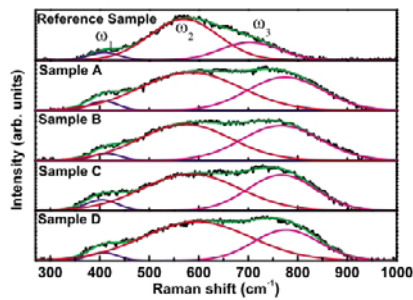
## Dynamic conductivity of graphene with electron-LO-phonon interaction

We calculate the electrical conductivity of single-layer graphene within the regime of massless Dirac fermions. We consider the electron-LO-phonon interactions as the dominant scattering mechanism. By using the Green's-function method, we are able to obtain the quantitative contribution from the five leading diagrams in the high-frequency approximation. It is found that electron-LO-phonon interactions cause an increase to the electromagnetic absorption of single-layer graphene of as much as 20% at room temperature. The spectrum is dominated by a continuum contribution with a peak at  $\omega = \omega_{\text{LO}}/2$  and represents intraband transitions. The temperature and doping dependence of these peak corrections is also investigated. These results probe the validity of the universal conductivity of graphene with respect to electron-phonon interactions under a range of conditions. (A. R. Wright et al., Physical Review B 81, 165413 (2010))



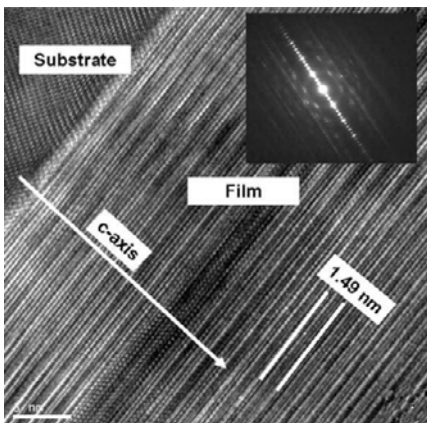
## A combined hydrogen storage system of $\text{Mg}(\text{BH}_4)_2$ - $\text{LiNH}_2$ with favorable dehydrogenation

The decomposition properties of  $\text{Mg}(\text{BH}_4)_2$ - $\text{LiNH}_2$  mixtures were investigated. Apparent  $\text{NH}_3$  release appeared from 50 to 300 °C for the  $\text{Mg}(\text{BH}_4)_2$ - $\text{LiNH}_2$  mixtures with mole ratios of 1:1.5, 1:2, and 1:3, while only hydrogen release was detected for the mixture with a mole ratio of 1:1. In the case of the  $\text{Mg}(\text{BH}_4)_2$ - $\text{LiNH}_2$  (1:1) sample, the onset of the first-step dehydrogenation starts at 160 °C, with a weight loss of 7.2 wt % at similar to 300 °C, which is improved significantly compared to the pure  $\text{Mg}(\text{BH}_4)_2$  alone. From Kissinger's method, the activation energy,  $E_a$ , for the first and second step dehydrogenation in  $\text{Mg}(\text{BH}_4)_2$ - $\text{LiNH}_2$  (1:1) was estimated to be about 121.7 and 236.6  $\text{kJ mol}^{-1}$ , respectively. The improved dehydrogenation in the combined system may be ascribed to a combination reaction between  $[\text{BH}_4]$  and  $[\text{NH}_2]$ , resulting in the formation of Li-Mg alloy and amorphous B-N compound. (X. B. Yu et al., Journal of Physical Chemistry C 114, 4733 (2010))



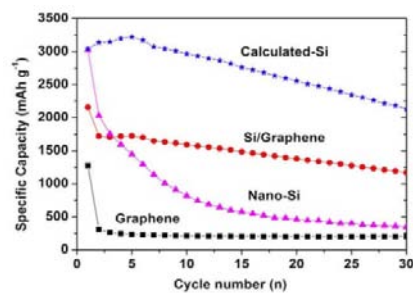
### Effect of Mg/B ratio on the superconductivity of MgB<sub>2</sub> bulk with SiC addition

To improve the self-field critical current density ( $J_c$ ) and critical temperature ( $T_c$ ) in SiC-doped MgB<sub>2</sub>, optimization of the nominal Mg/B mixing ratio has been performed. The effects of the nominal Mg/B mixing ratio ( $x:2$ ) on the superconductivity, Raman spectra, current transport properties, and flux pinning mechanisms in MgB<sub>2</sub> with 10 wt.% SiC doping were investigated systematically, with  $x$  varied from 1 to 1.2. It has been found that the sample with the Mg/B ratio of 1.15:2 exhibited the best  $J_c$  performance for all fields (0-8.5 T), and its  $T_c$  was also enhanced. The optimized Mg/B ratio diminished the interband scattering caused by Mg or B vacancies, and in turn, increased  $T_c$ . The connectivity and disorder were increased in the Mg<sub>1.15</sub>B<sub>2</sub> sample. Both of these were responsible for the improved  $J_c$  under all the fields examined. (Y. Zhang et al., Physical Review B 81, 094501 (2010))



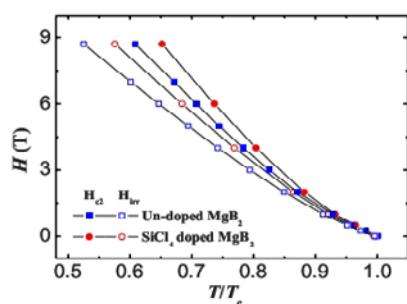
### (001)-oriented Bi<sub>2</sub>Sr<sub>2</sub>Co<sub>2</sub>O<sub>y</sub> and Ca<sub>3</sub>Co<sub>4</sub>O<sub>9</sub> films: Self-assembly orientation and growth mechanism by chemical solution deposition

In this study, two typical cobaltate-based thermoelectric films, Bi<sub>2</sub>Sr<sub>2</sub>Co<sub>2</sub>O<sub>y</sub> (BSC) and Ca<sub>3</sub>Co<sub>4</sub>O<sub>9</sub> (CCO), with structures of [Bi<sub>2</sub>Sr<sub>2</sub>O<sub>4</sub>][CoO<sub>2</sub>]<sub>2</sub> and [Ca<sub>2</sub>CoO<sub>3</sub>](Rs)[CoO<sub>2</sub>], respectively, are prepared by a simple chemical solution deposition on SrTiO<sub>3</sub> (1 0 0), (1 1 0), and (1 1 1) single crystal substrates. X-ray results reveal that all films are c-axis oriented regardless of the orientation of the substrate, suggesting self-assembly orientation. Transmission electron microscopy reveals amorphous/delamination regions for BSC film on SrTiO<sub>3</sub> (1 1 0), and the c-axis stripes of CCO on SrTiO<sub>3</sub> (1 1 1) are inclined at 30° to the interface, whereas the c-axis stripes are parallel to the interfaces for other films. The growth mechanism is established, and the driving force for self-assembly c-axis orientation is attributed to the syneresis stress due to solvent evaporation. The microstructures and properties are also studied and discussed, with the conclusion that self-assembly c-axis oriented layered cobaltates films are good candidates for thermoelectric applications. (X. B. Zhu et al., Acta Materialia 58, 4281 (2010))



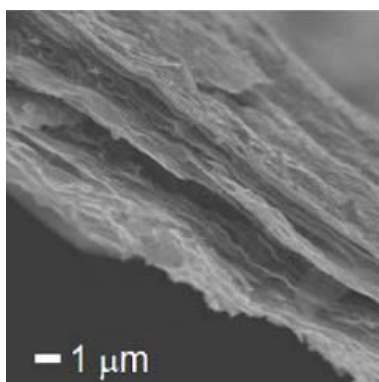
### Enhanced reversible lithium storage in a nanosize silicon/graphene composite

Si/graphene composite was prepared by simply mixing of commercially available nanosize Si and graphene. Electrochemical tests show that the Si/graphene composite maintains a capacity of 1168 mAh g<sup>-1</sup> and an average coulombic efficiency of 93% up to 30 cycles. EIS indicates that the Si/graphene composite electrode has less than 50% of the charge-transfer resistance compared with nanosize Si electrode, evidencing the enhanced ionic conductivity of Si/graphene composite. The enhanced cycling stability is attributed to the fact that the Si/graphene composite can accommodate large volume change of Si and maintain good electronic contact. (S. L. Chou et al., Electrochemistry Communications 12, 303 (2010))



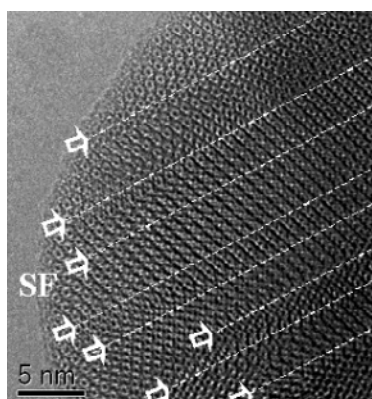
### Enhancement of the in-field $J_c$ of $MgB_2$ via $SiCl_4$ doping

We present the following results. (1) We introduce a doping source for  $MgB_2$ , liquid  $SiCl_4$ , which is free of C, to significantly enhance the irreversibility field ( $H_{irr}$ ), the upper critical field ( $H_{c2}$ ), and the critical current density ( $J_c$ ) with a little reduction in the critical temperature ( $T_c$ ). (2) Although Si can not be incorporated into the crystal lattice, a significant reduction in the a-axis lattice parameter was found, to the same extent as for carbon doping. (3) Based on the first-principles calculation, it is found that it is reliable to estimate the C concentration just from the reduction in the a-lattice parameter for C-doped  $MgB_2$  polycrystalline samples that are prepared at high sintering temperatures, but not for those prepared at low sintering temperatures. Strain effects and magnesium deficiency might be reasons for the a-lattice reduction in non-C or some of the C-added  $MgB_2$  samples. (4) The  $SiCl_4$ -doped  $MgB_2$  shows much higher  $J_c$  with superior field dependence above 20 K compared to undoped  $MgB_2$  and  $MgB_2$  doped with various carbon sources. (5) We introduce a parameter, RHH ( $H_{c2}/H_{irr}$ ), which can clearly reflect the degree of flux-pinning enhancement, providing us with guidance for further enhancing  $J_c$ . (6) It was found that spatial variation in the charge-carrier mean free path is responsible for the flux-pinning mechanism in the  $SiCl_4$  treated  $MgB_2$  with large in-field  $J_c$ . (X. L. Wang et al., Physical Review B 81, 224514 (2010))



### Flexible free-standing graphene-silicon composite film for lithium-ion batteries

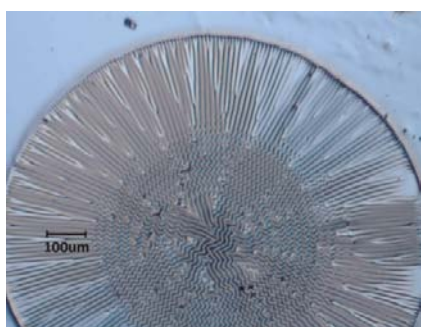
Flexible, free-standing, paper-like, graphene-silicon composite materials have been synthesized by a simple, one-step, in-situ filtration method. The Si nanoparticles are highly encapsulated in a graphene nanosheet matrix. The electrochemical results show that graphene-Si composite film has much higher discharge capacity beyond 100 cycles ( $708 \text{ mAh g}^{-1}$ ) than that of the cell with pure graphene ( $304 \text{ mAh g}^{-1}$ ). The graphene functions as a flexible mechanical support for strain release, offering an efficient electrically conducting channel, while the nanosized silicon provides the high capacity. (J. Z. Wang et al., Electrochemistry Communications 12, 1467 (2010))



### Comparative study of mono- and multi-filament $MgB_2$ wires with different boron powders and malic acid addition

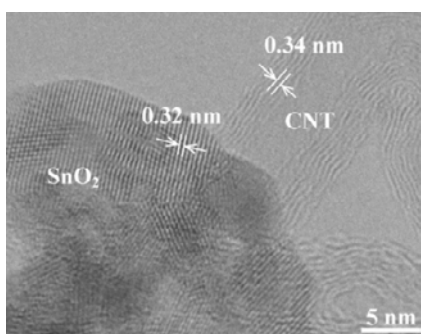
We evaluated the effects of different boron (B) powders and of malic acid ( $C_4H_6O_5$ ) addition on the critical current density ( $J_c$ ) of mono- and multi-filament  $MgB_2$  wires. We found that  $J_c$  of the wires made from the amorphous B showed the best performance. Low sintering processing keeps the grain size small, which leads to strong flux pinning. From transmission electron microscopy (TEM) observations, we confirmed that the crystalline B powders supplied by SMI and Tangshan had a beta-rhombohedral structure as a main phase. These two powders also had numerous defects, such as twin and stacking faults inside the powder particles. However, these defects are not enough to promote the full reaction between magnesium (Mg) and B crystalline powder when sintered at low temperatures, and brings about low  $J_c$  values. Even though the morphologies of the two crystalline B powders appeared somewhat different,  $J_c$  for the two wires had similar quantitative values. For the malic acid doped wires,  $J_c$  of the wire made from the amorphous B was estimated to be above  $100\,000 \text{ A cm}^{-2}$  at 6 T and 4.2 K. This value is comparable to the low temperature superconductor Nb-Ti. In addition, the  $J_c$  was  $25\,000 \text{ A cm}^{-2}$  at 10 T and 4.2 K. This performance is the best  $J_c$  reported so far in situ

processed  $\text{MgB}_2$  wires. Interestingly, the low-field  $J_c$  performance of malic acid doped wire fabricated with crystalline B is higher than that of the pure wire fabricated with amorphous B. At 20 K, enhanced performance of  $J_c$  by malic acid doping is much higher than that of the pure  $\text{MgB}_2$  wire. The  $J_c$  at 5 T and 20 K was estimated to be  $13\,000\text{ A cm}^{-2}$ . (J. H. Kim et al., Superconductor Science & Technology 23, 075014 (2010))



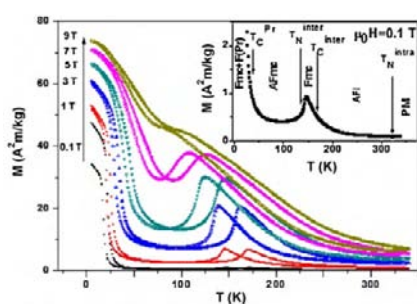
### The control of time-dependent buckling patterns in thin confined elastomer film

Low energy metal ion implantation has been used to combine an easy “bottom-up” way of creating and tuning different topographic structures on submicron to micrometer scales with the embedding of a metallic element-rich functionalized layer at the surface for a variety of scientific and technological applications. The self-organizing and complex patterns of functionalized topographic structures are highly dependent on the implanted metal ion species, variations in the geometric confinement of the buckled areas on the larger unmodified elastomer film, and the boundary conditions of the buckled regions. Systematic investigations of these dependencies have been carried out via optical and atomic force microscopy, and confirmed with cross-sectional transmission electron microscopy. (B. Winton et al., Journal of Materials Research 25, 1929 (2010))



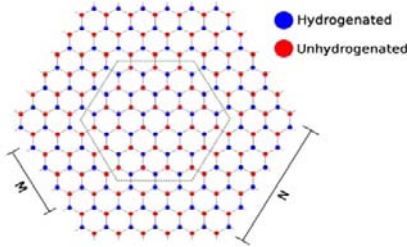
### $\text{SnO}_2$ -coated multiwall carbon nanotube composite anode materials for rechargeable lithium-ion batteries

$\text{SnO}_2$ -coated multiwall carbon nanotube (MWCNT) nanocomposites were synthesized by a facile hydrothermal method. The as-prepared nanocomposites were characterized by X-ray diffraction (XRD), field emission scanning electron microscopy (FE-SEM), transmission electron microscopy (TEM), and thermogravimetric analysis (TGA). The  $\text{SnO}_2$ /MWCNT composites, when combined with carboxymethyl cellulose (CMC) as a binder, show excellent cyclic retention, with the high specific capacity of  $473\text{ mAh g}^{-1}$  beyond 100 cycles, much greater than that of the bare  $\text{SnO}_2$ , which was also prepared by the hydrothermal method in the absence of MWCNTs. The enhanced capacity retention could be mainly attributed to good dispersion of the tin dioxide particles in the matrix of MWCNTs, which protected the particles from agglomeration during the cycling process. Furthermore, the usage of CMC as a binder is responsible for the low cost and environmental friendliness of the whole electrode fabrication process. (L. Noerochim et al., Electrochimica Acta 56, 314 (2010))



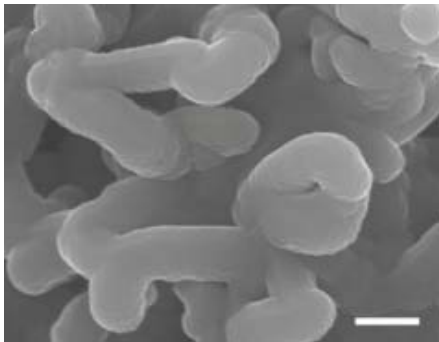
### Three first order magnetic phase transitions in re-entrant ferromagnet $\text{PrMn}_{1.4}\text{Fe}_{0.6}\text{Ge}_2$

Three first order magnetic phase transitions (FOMTs) have been detected and evaluated over the temperature range from 5 to 340 K at fields up to 9 T in  $\text{PrMn}_{1.4}\text{Fe}_{0.6}\text{Ge}_2$ . All three FOMTs, from (with decreasing temperature) an antiferromagnetic (AFI) to a c-axis canted ferromagnetic (Fmc) state, to a c-axis canted antiferromagnetic (AFmc) state, and then to an Fmc state plus an additional Pr-sublattice magnetic contribution (Fmc + F(Pr)), exhibited temperature and field-induced transition features. A interesting phenomenon was observed, in that magnetic field can induce an AFmc to Fmc + F(Pr) transition, and then diminish and finally eliminate the re-entrant magnetic transition behavior under high field as well. Based on systematic measurements and analysis, a magnetic phase diagram has been determined. (R. Zeng et al., Journal of Alloys and Compounds 53, 160 (2009))



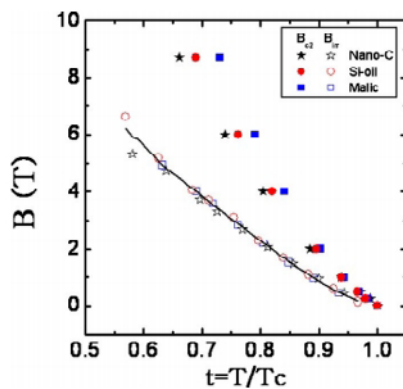
### Gapless insulator and a band gap scaling law in semihydrogenated graphene

We demonstrate two unusual electronic properties of semihydrogenated graphene with variable sized A- or B-hydrogenated domains within the tight-binding formalism as follows: (i) a universal band gap scaling law which states that the band gap depends linearly upon the ratio of the number of A- to B-hydrogenated atoms,  $N_A/N_B$ , reaching zero gap at  $N_A=N_B$ , but independent of the domain size, and (ii) an insulating state with zero band gap at  $N_A=N_B$ , a rare phenomenon in nature. We confirm this gapless insulator state by the zero optical conductance at low frequencies. (A. R. Wright et al., *Applied Physics Letters* 97, 043104 (2010))



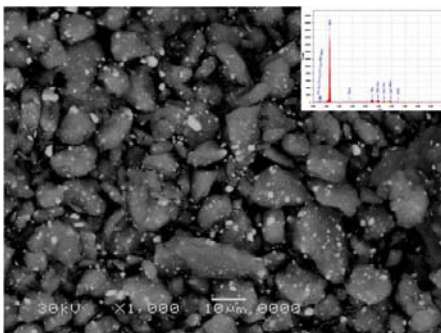
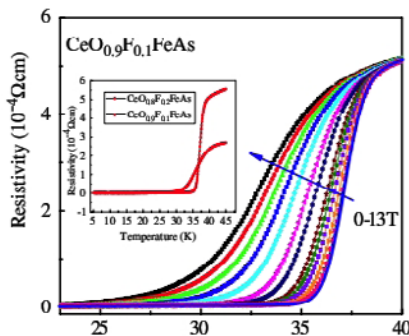
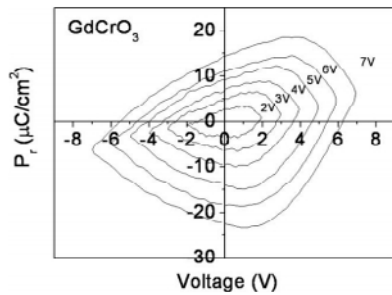
### Silicon/single-walled carbon nanotube composite paper as a flexible anode material for lithium ion batteries

Flexible silicon/single-walled carbon nanotube (Si/SWCNT) composite paper was prepared using the pulsed laser deposition (PLD) method to deposit Si onto SWCNT paper. In the composite, Si mainly shows nanoworm-like morphology. Increasing deposition time results in an increased amount of Si microspheres. Electrochemical measurements show that the capacity of the composite paper is improved by the presence of Si. The Si/SWCNT composite with only 2.2% Si shows a capacity of 163 mAh g<sup>-1</sup> at a current density of 25 mA g<sup>-1</sup> up to 50 cycles, which is more than 60% improvement of the capacity of pristine CNT paper. The Si contribution in the 2.2%-Si/SWCNT sample is calculated to be higher than 3000 mA h g<sup>-1</sup>. (S. L. Chou et al., *Journal of Physical Chemistry C* 114, 15862 (2010))



### Strong competition between the $I$ and $T_c$ flux pinning mechanisms in $MgB_2$ doped with carbon containing compounds

The transport and magnetic properties of 10 wt % malic acid and 5 wt % nanocarbon doped  $MgB_2$  have been studied by measuring the resistivity ( $\rho$ ), critical current density ( $j_c$ ), connectivity factor ( $A_F$ ), irreversibility field ( $H_{irr}$ ), and upper critical field ( $H_{c2}$ ). The pinning mechanisms are studied in terms of the collective pinning model. It was found that both mean free path ( $l$ ) and critical temperature ( $T_c$ ) pinning mechanisms coexist in both doped  $MgB_2$ . For both the malic acid and nanocarbon doped samples, the temperature dependence of the crossover field, which separates the single vortex and the small bundle pinning regime,  $B_{sb}(T)$ , shows that the  $l$  pinning mechanism is dominant for temperatures up to  $t(T/T_c)=0.7$  but the  $T_c$  pinning mechanism is dominant for  $t>0.7$ . This tendency of coexistence of the  $l$  and the  $T_c$  pinning mechanism is in strong contrast with the pure  $MgB_2$ , in which the  $T_c$  pinning mechanism is dominant over a wide temperature range below  $T_c$ . It was also observed that the connectivity factor, active cross-sectional area fraction ( $A_F$ ), are 0.11 and 0.14 for the nanocarbon and the malic acid doped  $MgB_2$ , respectively, indicating that there are still rooms for further improving  $j_c$  performance. (S. R. Ghorbani et al., *Journal of Applied Physics* 107, 113921 (2010))



## A novel multiferroic system: Rare earth chromates

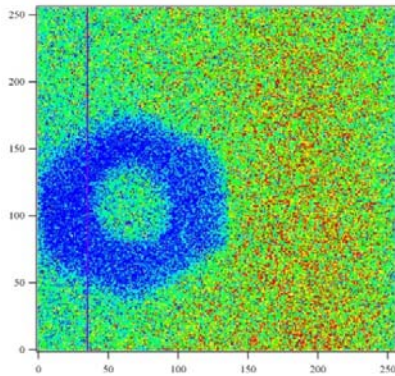
In this work, we report on our studies on the multiferroic properties of two rare earth chromates,  $\text{GdCrO}_3$  and  $\text{YCrO}_3$ . Polycrystalline bulks and thin films have been fabricated using conventional solid state reaction and pulsed laser deposition. Magnetic measurements have revealed that both compounds show weak ferromagnetism below the antiferromagnetic Neel temperature,  $T_N$ , of 170 and 140 K for  $\text{GdCrO}_3$  and  $\text{YCrO}_3$ , respectively. However the well-developed ferroelectric polarization electrical field loop was not successfully measured for both samples due to their low resistance. The high conductivity of the samples at room temperature is related to the thermal activation of charge carriers at around 200 K in the samples revealed by temperature dependent dielectric measurement. Capacitance measurement at 77 K within magnetic field of 3000 Oe and zero field for  $\text{GdCrO}_3$  bulk sample shows an increase in 58% in capacitance at 400 kHz by a magnetic field. (Z. X. Cheng et al., *Journal of Applied Physics* 107, 09D905 (2010))

## Upper critical field, critical current density and thermally activated flux flow in fluorine doped $\text{CeFeAsO}$ superconductors

We report our studies on the crystal structures, morphologies, and superconductivity in  $\text{CeO}_{1-x}\text{F}_x\text{FeAs}$  compounds which were fabricated by solid state reaction. The crystal structures were refined using Rietveld refinement. Superconducting properties such as critical temperature ( $T_c$ ), critical current density ( $J_c$ ), and upper critical field ( $H_{c2}$ ) were determined using magneto-transport and magnetic measurement over a wide range of temperature below  $T_c$ , and in magnetic fields up to 13 T.  $J_c$  is  $2 \times 10^3 \text{ A cm}^{-2}$  for the  $x = 0.1$  sample. However, the  $J_c$  exhibited a weak dependence on magnetic field for  $B > 1 \text{ T}$  and  $T = 5$  and  $10 \text{ K}$ . A peak effect in the  $J_c$  as a function of field was observed at 20 K in the  $x = 0.1$  sample. We estimate  $H_{c2}(\text{ab})$  of 185 T for  $\text{CeO}_{0.9}\text{F}_{0.1}\text{FeAs}$  compound. The broadening of the superconducting transition near  $T_c$  with increasing field can be well understood using the thermal activated flux flow model. The pinning potential scales as  $U_0/K_B \propto B^{-n}$  with  $n = 0.2$  for  $B < 3 \text{ T}$  and  $n = 0.71$  for  $B > 3 \text{ T}$  in the  $x = 0.1$  sample. (M. Shahbazi et al., *Superconductor Science & Technology* 23, 105008 (2010))

## Effects of CNTs on the hydrogen storage properties of $\text{MgH}_2$ and $\text{MgH}_2$ -BCC composite

$\text{MgH}_2$  with 10 wt.%  $\text{Ti}_{0.4}\text{Mn}_{0.22}\text{Cr}_{0.1}\text{V}_{0.28}$  alloy (termed the BCC alloy for its body centred cubic structure) and 5 wt.% carbon nanotubes (CNTs) were prepared by planetary ball milling, and its hydrogen storage properties were compared with those of the pure  $\text{MgH}_2$  and the binary mixture of  $\text{MgH}_2$  and the BCC alloy. The sample with CNTs showed considerable improvement in hydrogen sorption properties. Its temperature of desorption was 125 °C lower than for the pure sample and 59 °C lower than for the binary mixture. In addition, the gravimetric capacity of the ternary sample was 6 wt.% at 300 °C and 5.6 wt.% at 250 °C, and it absorbed 90% of this amount at 150 s and 516 s at 300 °C and 250 °C, respectively. It can be hypothesised from the results that the BCC alloy assists the disso-ciation of hydrogen molecules into hydrogen atoms and also promotes hydrogen pumping into the Mg/BCC interfaces, while the CNTs facilitate access of H-atoms into the interior of Mg grains. (A. Ranjbar et al., *International Journal of Hydrogen Energy* 35, 7821 (2010))



## Mechanisms of x-ray emission from peeling adhesive tape

It has previously been reported that x-rays are emitted when adhesive tape is peeled in a vacuum but no account of the dependence of the x-ray emission on the pressure of the environment has been given to date. In this paper we present detailed experimental data on the number and angular distribution of x-ray photons as a function of pressure. We find that x-rays are emitted for pressures between  $p_0=10^{-3}$  and  $p_1=10^{-2}$  mBar, with  $\sim 10^6$  counts/( $\text{cm}^2\text{s}$ ) recorded by  $256 \times 256$  pixel<sup>2</sup> silicon array sensor placed 35 mm from the tape. The main role of the tape is found to be the build-up of an acceleration potential sufficient to produce x-rays by bremsstrahlung of free electrons in a low-pressure gas. The source of the free electrons is the gas. Our model shows that the production rate of uncompensated tape charge and absorption of positive ions from the gas define  $p_1$ . The angular distribution of the radiation shows a pressure-independent  $20^\circ$  wide peak in the direction perpendicular to electron motion. Ordinary bremsstrahlung cannot describe this peak. (E. Constable et al., Applied Physics Letters 97, 131502 (2010))

# Conferences

## Conference Participation

### **3<sup>RD</sup> IEEE INTERNATIONAL NANO-ELECTRONIC CONFERENCE (3<sup>RD</sup> TO 8<sup>TH</sup> JANUARY 2010, HONG KONG, CHINA)**

Session Chair: X. L. Wang

### **11<sup>TH</sup> JOINT MMM ANNUAL CONFERENCE (18<sup>TH</sup> TO 22<sup>ND</sup> JANUARY 2010, WASHINGTON DC, UNITED STATES OF AMERICA)**

"A novel multiferroic system: Rare earth chromates", Z. X. Cheng

### **MC10SPM MATERIALS CHALLENGES CONFERENCE (21<sup>ST</sup> TO 24<sup>TH</sup> FEBRUARY 2010, FLORIDA, UNITED STATES OF AMERICA)**

"Structural study and hydrogen sorption kinetics of ball-milled samples of cast Mg-10%Ni catalysed by Nb", S. Aminoroaya

### **INTERNATIONAL CONFERENCE ON SUPERCONDUCTIVITY AND MAGNETISM (20<sup>TH</sup> TO 25<sup>TH</sup> APRIL 2010, ANTALYA, TURKEY)**

"Chemical doping and strain effect for improvement in  $J_c$  and  $H_{irr}$  and  $H_{c2}$  in  $MgB_2$ ", S. X. Dou (Invited)

### **INTERNATIONAL WORKSHOP ON SUPERCONDUCTIVITY AND LOW DIMENSIONALITY (4<sup>TH</sup> TO 8<sup>TH</sup> MAY 2010, ANTALYA, SALZBERG)**

"Nano-doping and nano-strain effect in  $MgB_2$ ", S. X. Dou (Invited)

### **15<sup>TH</sup> INTERNATIONAL MEETING ON LITHIUM BATTERIES (27<sup>TH</sup> JUNE TO 2<sup>ND</sup> JULY 2010, MONTREAL, CANADA)**

"Microwave-assisted synthesis of alpha and epsilon  $MnO_2$  as cathode materials for lithium ion batteries", G. Du (Poster)

"Sulfur-graphene composite for rechargeable lithium batteries", J. Z. Wang

"High capacity and high rate capability of nanostructured  $CuFeO_2$  anode materials for lithium-ion batteries", J. Z. Wang

### **KOREAN SUPERCONDUCTIVITY SYMPOSIUM (7<sup>TH</sup> JULY TO 9<sup>TH</sup> JULY 2010, YONGPYOUNG, KOREA)**

"Progress in Fe based superconductor and  $MgB_2$ ", S. X. Dou (Invited)

### **INTERNATIONAL SYMPOSIUM: METAL HYDROGEN SYSTEMS (19<sup>TH</sup> JULY TO 23<sup>RD</sup> JULY 2010, MOSCOW, RUSSIA)**

"Thermal decomposition performance of  $Ca(BH_4)_2/LiNH_2$  mixtures", X. Yu

### **CHINESE OVERSEAS TECHNOLOGY FORUM (25<sup>TH</sup> TO 26<sup>TH</sup> JULY 2010, GUANGZHOU, CHINA)**

"Innovative materials present new opportunities for next generation manufactures", S. X. Dou (Invited)

### **APPLIED SUPERCONDUCTIVITY CONFERENCE (1<sup>ST</sup> AUGUST TO 6<sup>TH</sup> AUGUST 2010, WASHINGTON DC, UNITED STATES OF AMERICA)**

"Very high pinning potential of iron based superconductor single crystal 122", S. X. Dou

"Multi-terminal superconducting non-equilibrium device with a ferromagnetic screen", I. Nevirkovets

"Solution derived  $Sm_2O_3$  films on biaxially textured Ni-W substrates", L. Lu (Poster)

### **7<sup>TH</sup> PACIFIC RIM INTERNATIONAL CONFERENCE ON ADVANCED MATERIALS AND PROCESSING (2<sup>ND</sup> AUGUST TO 6<sup>TH</sup> AUGUST 2010, CAIRNS, AUSTRALIA)**

"Step-edge Josephson junctions on multilayered high temperature superconducting thin film", O. Shcherbakova (Poster)

### **INTERNATIONAL UNION OF MATERIALS RESEARCH SOCIETIES - INTERNATIONAL CONFERENCE ON ELECTRONIC MATERIALS (22<sup>ND</sup> TO 27<sup>TH</sup> AUGUST, 2010, SEOUL, KOREA)**

Session Chair: X. L. Wang & J. Z. Wang

"Latest progress of Fe-based superconductors", X. L. Wang (Invited)

"The Effects of graphene doping on the in-field  $J_c$  of  $MgB_2$  wires", X. Xu

**VIRTUAL CONFERENCE ON NANO-SCALE SCIENCE AND TECHNOLOGY (30<sup>TH</sup> TO 31<sup>ST</sup> AUGUST, SYDNEY, AUSTRALIA)**

"Chemical doping and strain control for materials design and formulation", S. X. Dou (Invited)

**3<sup>RD</sup> AUSTRALIA-CHINA JOINT SYMPOSIUM ON SCIENCE, TECHNOLOGY AND EDUCATION (6<sup>TH</sup> TO 8<sup>TH</sup> OCTOBER 2010, MELBOURNE, AUSTRALIA)**

"One-dimensional nanoporous nanowires as electrode materials for lithium ion batteries" Z. P. Guo

**EXPERIMENTAL CONDENSED MATTER PHYSICS CONFERENCE (25<sup>TH</sup> TO 29<sup>TH</sup> OCTOBER 2010, KOLKATA, INDIA)**

"LiFePO<sub>4</sub>-Fe<sub>2</sub>P-C composite cathode: Synthesis, magnetic properties study and its electrochemical performances for lithium-ion batteries", M. M. Rahman (Poster)

**5<sup>TH</sup> INTERNATIONAL FORUM ON LI ION BATTERY TECHNOLOGY & INDUSTRY DEVELOPMENT MATERIALS SCIENCE SYMPOSIUM (4<sup>TH</sup> TO 7<sup>TH</sup> NOVEMBER 2010, BEIJING, CHINA)**

"Electric vehicle power development prospects in Australia", S. X. Dou (Invited)

**INTERNATIONAL MATERIALS FORUM (8<sup>TH</sup> TO 11<sup>TH</sup> NOVEMBER 2010, TOKYO, JAPAN)**

"Nano structure control for materials formulation", S. X. Dou (Invited)

**3<sup>RD</sup> INTERNATIONAL CONGRESS ON CERAMICS (14<sup>TH</sup> TO 18<sup>TH</sup> NOVEMBER 2010, OSAKA, JAPAN)**

"Development of MgB<sub>2</sub> superconducting wires for practical applications", J. H. Kim (Invited)

**55<sup>TH</sup> MAGNETISM & MAGNETIC MATERIALS CONFERENCE (14<sup>TH</sup> TO 18<sup>TH</sup> NOVEMBER 2010, ATLANTA, UNITED STATES OF AMERICA)**

"Magnetic phase transition and Mössbauer spectroscopy of ErNi<sub>2</sub>Mn compound", J. Wang

"Upper critical field and thermally activated flux flow in LaFeAsO<sub>1-x</sub>Fx compounds", M. Shahbazi (Poster)

"Magnetoresistance, critical current density and flux pinning mechanism in Nickel doped BaFe<sub>2</sub>As<sub>2</sub> single crystal", M. Shahbazi (Poster)

**9<sup>TH</sup> CHINA INTERNATIONAL NANOSCIENCE & TECHNOLOGY SYMPOSIUM (15<sup>TH</sup> TO 19<sup>TH</sup> NOVEMBER 2010, XIAN, CHINA)**

"A GBH/LiBH<sub>4</sub> coordination system with favorable dehydrogenation", X. Yu

**7<sup>TH</sup> ANNUAL CONFERENCE OF THE ARC CENTER OF EXCELLENCE FOR FUNCTIONAL NANOMATERIALS, (25<sup>TH</sup> TO 26<sup>TH</sup> NOVEMBER 2010, GOLD COAST, AUSTRALIA)**

Key Note Speaker: H. K. Liu

"Nano-materials for lithium rechargeable battery and supercapacitors", H. K. Liu

# Honorary Appointment in Overseas Institutes



## **S. X. Dou**

- ▶ Asia Materials, Branch of Nature Materials, Advisory Committee
- ▶ Beijing University of Science and Technology, Beijing, China
- ▶ Hubei University, China
- ▶ Shanghai University, China
- ▶ Institute of Electrical Engineering, Chinese Academy of Sciences, China
- ▶ Open Materials Science Journal, Editor Board Member
- ▶ Rare Earth Metals, Associate Editor
- ▶ Shanghai Institute of Microsystems and Information Technology, Chinese Academy of Sciences, Shanghai, China

## **H. K. Liu**

- ▶ Advanced Science Letters, Associate Editor
- ▶ Hubei University, China
- ▶ Shanghai University, China
- ▶ Journal of Nanoscience and Nanotechnology, Editorial Board Member
- ▶ Journal of New Materials for Electrochemical Systems, Advisory Board Member
- ▶ Shanghai Institute of Microsystems and Information Technology, Chinese Academy of Sciences, Shanghai, China

## **C. Zhang**

- ▶ Institute of Solid State Physics, Chinese Academy of Sciences
- ▶ Shanghai Institute of Microsystems and Information Technology, Chinese Academy of Sciences, Shanghai, China
- ▶ Tianjin University, Tianjin, China
- ▶ Xi'an Institute of Optics and Precise Mechanics, Chinese Academy of Sciences, Xi'an, China

## **Z. P. Guo**

- ▶ East China University of Science and Technology
- ▶ Xinjiang University

# Invited Presentations and Seminars at Other Institutions



## Invited Talks, Presentations, Seminars

### S. X. Dou

- ▶ "Introduction to ISEM research program"  
Dalian University of Science and Technology, China, July 2010 (photo – Dalian)
- ▶ "Introduction to ISEM research and postgraduate training program"  
Northeastern University, China, July 2010
- ▶ "Introduction to ISEM research and postgraduate training program"  
Beijing Hong Tien University, China, July 2010
- ▶ "Introduction to ISEM research and postgraduate training program"  
Non-ferrous Research Institute, China, July 2010
- ▶ "How a small University can have strong research program"  
Hua Qiao University, China, November 2010

### C. Zhang

- ▶ "Hall effect on graphene nano ribbons"  
Tokai University, Japan, March 2010
- ▶ "Quantum transport in graphene"  
Xian University of Technology, China, April 2010

### R. A. Lewis

- ▶ "A cornucopia of terahertz",  
Technical University of Darmstadt, Germany, April 2010

### Z. P. Guo

- ▶ "Lithium ion battery research at University of Wollongong"  
Xinjiang University, Urumqi, China, January 2010
- ▶ "Porous anode thin film electrodes for lithium ion micro-batteries"  
HuBei University, Wuhan, China, June 2010
- ▶ "Lithium ion batteries for electric vehicles"  
DLG Battery Co. Ltd, Shanghai, China, June 2010
- ▶ "Advanced anode materials for lithium ion batteries"  
Shanghai Jiaotong University, Shanghai China, July 2010

### H. K. Liu

- ▶ "Advanced materials for Li-ion batteries"  
Institute of Materials Science, Shanghai University, China, July 2010
- ▶ "Advanced materials for Li-ion batteries"  
Institute of Nonferrous Metals, China, July 2010
- ▶ "Nanomaterials and nanotechnologies for lithium rechargeable batteries"  
The School of Chemical Sciences and Engineering, UNSW, Australia, November 2010

# Seminars by Visiting Scientists

Date	Name	Institute	Title
25/1/2010	Prof Edward W Collings	Centre for Superconducting and Magnetic Materials (CSMM) The Ohio State University Columbus Ohio USA	Formation, Flux Pinning, Connectivity, and the Evolution of Structural and Superconducting Properties with Heat Treatment Time in in-situ-C-doped MgB <sub>2</sub>
4/2/2010	Dr Nestor J Zaluzec	Electron Microscopy Center Materials Science Division Argonne National Laboratory	Characterizing the nano-world: a picture is no longer worth a thousand words
9/2/2010	Prof Ernst Helmut Brandt	Max Planck Institute for Metals Research, Stuttgart, Germany	Magnetic Vortices in Superconductors: Ideal Lattice, Pinning, and Geometry Effects
23/2/2010	Dr Klaus Lips	Helmholtz-Zentrum Berlin für Materialien und Energie Institut für Silizium-Photovoltaik, Kekuléstr. 5, D-12489 Berlin, Germany	Thin-film silicon photovoltaics - a huge potential and a grand challenge
26/2/2010	Dr Xuechu Shen	Shanghai Institute of Technical Physics, Chinese Academy of Sciences & Physics Dept. Fudan University, Shanghai, 200083, China	Electron: A Strange Particle & A Smart Spirit- New and Chaotic Face of electron as seen by THz Spectroscopy
2/3/2010	Dr Kiyoshi Ozawa	National Institute for materials Science, Materials Engineering Laboratory, Japan	Cathode Materials for Li-ion batteries
5/3/2010	Prof Mukunda Das	Department of Theoretical Physics, Australian National University	Kohn Anomaly in Conventional Superconductors: A surprise
13/5/2010	Prof/Dr Ketack Kim	Battery Research Group, Korea Electrotechnology Research Institute, and an adjunct Professor at University of Science & Technology. Supported by the Energy Futures Network	Thermal studies and safety enhancement by electrolytes in Li-ion battery
17/5/2010	Prof Oumarou Savadogo	Laboratory of New Materials for Electrochemistry and Energy École Polytechnique de Montréal, Canada Supported by the Energy Futures Network	Search for new families of electro catalysts for the ORR Cathodes for PEM Fuel Cell Applications
26/5/2010	Dr Vincent Wallace	School of Physics, University of Western Australia	Biomedical Applications of THz radiation
11/6/10	Prof Mukunda P Das	Department of Theoretical Physics, The Australian National University, Canberra, Australia	Super-Phenomena in the Quantum world
21/6/10	Prof Hideo Takezoe	Department of Organic and Polymeric Materials, Tokyo Institute of Technology And Chief Editor of Asia Materials	Ferroelectricity and Antiferroelectricity in Liquid Crystals
2/7/10	Dr David R. G. Mitchell	Laboratory Manager ACMM, University of Sydney	Recent Developments in Transmission Electron Microscopy at the Australian Centre for Microscopy and Microanalysis (ACMM)
15/7/10	Dr Sheikh A Akbar	NSF Center for Industrial Sensors and Measurements (CISM), Ohio State University (OSU), Columbus, OH, USA	Ceramic Nano-structures without Lithography: Platforms for Novel Applications

Date	Name	Institute	Title
16/8/10	Prof Ganpati Ramanath	Materials Science and Engineering Department, Rensselaer Polytechnic Institute, Troy, NY, USA	Molecularly-directed sculpture and tailoring of nanostructures, assemblies and interfaces
18/8/10	Dr Thomas Pfeifer	Leica Microsystems, Vienna	SEM Sample Preparation in materials science by using ion beam slope cutting.
1/9/10	Dr YongMook Kang	Div. of Advanced Materials Engineering, Kongju National University, Republic of Korea	Novel synthetic and analytic ways for electrode materials in Li ion battery
10/9/10	Prof Kevin O'Grady	Department of Physics, The University of York, Heslington, York, U.K	A New Paradigm for Exchange Bias in Polycrystalline Films
17/9/10	Dr Adrian Lowe	School of Engineering, Australian National University	Electroceraamics Research at the Australian National University
7/10/10	Dr Tadeusz Bak	Solar Energy Technologies School of Natural Sciences, University of Western Sydney	Charge Transfer at the Oxygen/Zirconia Interface: Impact on Electrochemical Energy Conversion
7/10/10	Prof Janusz Nowotny	Solar Energy Technologies School of Natural Sciences, University of Western Sydney	TiO <sub>2</sub> -Based Photosensitive Oxide Semiconductors for Solar Energy Conversion
19/10/10	Dr Ting Liao	University of Queensland	Density functional theory calculations for mechanical property optimization and defect behaviors: Application to MAX-phase
18/11/10	Dr Dae-Yeong Jeong	Electro-functionality Materials Engineering, Korea Electrotechnology Research Institute Campus, University of Science & Technology	Recent R&D activities of Advanced Materials & Application Research Division (AMARD) of Korea Electrotechnology Research Institute (KERI)
26/11/10	<sup>1</sup> Dr Simon KH Lam, <sup>1</sup> Dr Peter F Vohralik & <sup>2</sup> Dr Wenrong Yang	<sup>1</sup> CSIRO Materials Science and Engineering, Lindfield, Australia <sup>2</sup> Australian Key Centre for Microscopy and Mircoanalysis (AKCMM), Electron Microscopy Unit, University of Sydney, Australia	Nanoscale SQUID for the detection of magnetic nanoparticle macroscopic-spin states
1/12/10	Dr Etsuo Kawate	National Institute of Advanced Industrial Science and Technology (AIST) and TRAS Inc., Shimohirooka, Japan	An Optical Device for Absolute Reflectance and Transmittance Measurements of a Specular Sample at a Continuously Variable Angle of Incidence from 0 to 90 Degrees
21/12/10	Dr Tai-Feng Hung	Department of Chemistry, National Taiwan University, Taipei, R.O.C	Novel Materials of Membrane Electrode Assembly for Proton Exchange Membrane Fuel Cell Application
22/12/10	Richard Trett	AXT Pty Ltd	Overview of the Xradia products and their applications

# Equipment and Facilities

In 2010 ISEM continued to improve its laboratory equipment and expand its capabilities in materials fabrication and characterisation.

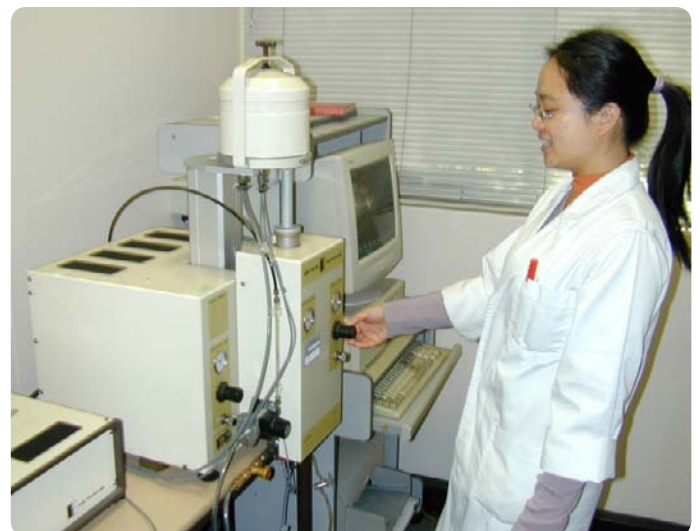
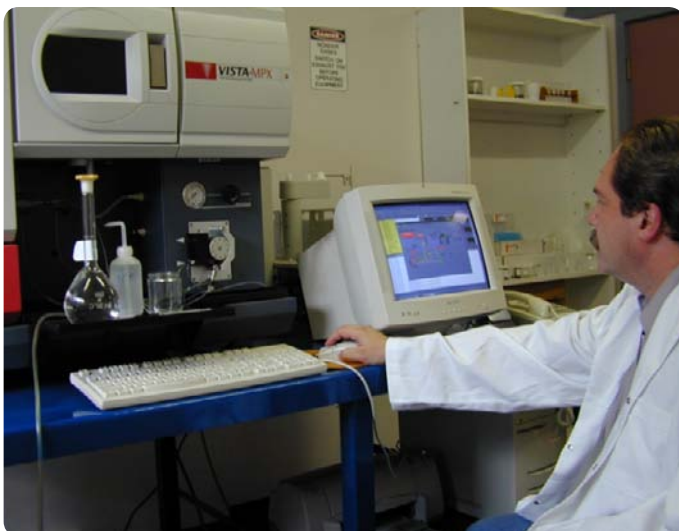
Currently ISEM has approximately 900m<sup>2</sup> and 21 labs in the Australian Institute for Innovative Materials (AIIM) Facility at the University of Wollongong's Innovation Campus. This large available laboratory space will expand even further, when the new AIIM Processing and Devices (AIIM P&D) facility becomes operational. New specialised laboratories, such as high grade clean room, HTS prototyping, nano-materials processing and others will be established, increasing ISEMs capacity to develop the new production processes and devices needed to commercialise breakthrough research.

Some of the major facilities were founded and purchased through nine ARC LIEF grants, the Metal Manufactures Ltd Consortium program and industry partners support over the past decade. Significant funding was also available through the relocation budget and new AIIM P&D

project funding. We have purchased some of the best facilities available, such as Mettler Toledo TGA/DTA for materials characterisation, powerful solid state laser (Quanta Ray) for deposition of thin films and optical table, four mirror floating zone single crystal growth facility (CSC Corporation) for growth of large high quality single crystals, new GBC MMA XRD machine with most up-to-date PDF2 database, scanning tunnelling, scanning probe and scanning near field optical microscopes (Unisoku Co), a maskless lithography system (Heidelberg), and other equipment.

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

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



## Materials Processing Facilities

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

## Thin Film Deposition and Structuring Facilities

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

## Materials Characterisation

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

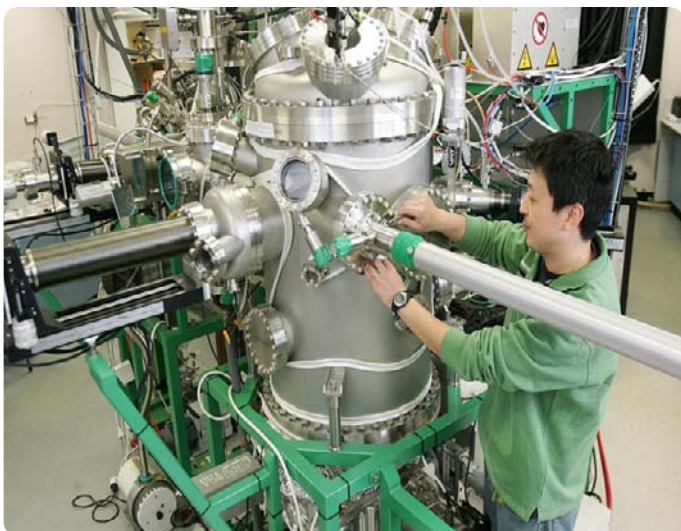


**Pictured left to right (p62–63):**

ICP-OES, Vista Simultaneous Axial Spectrometer  
 Setaram high-temperature DTA/TGA instrument  
 Magnetic Property Measurement System 4K-300K, 0-5T

## Physical Property Characterisation

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



## Electro-Chemical Property Characterisation

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



**Pictured left to right (p64–65):**

Electron Beam Evaporation Facility

High-resolution JEOL SEM/EBL system

Glove box for controller atmosphere environment

# Refereed Publications



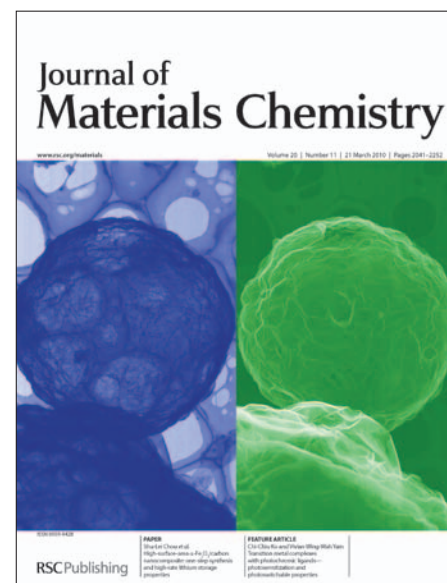
## Scholarly books

1. O. V. Shcherbakova, A. V. Pan, S. X. Dou, "Magnesium diboride superconductors: development and properties", Published by VDM Verlag Dr. Muller Aktiengesellschaft & Co. KG (2010).
2. W. X. Li and S. X. Dou, "Superconducting properties of carbonaceous chemical doped  $MgB_2$ ", Adir Moysés Luiz (editor) Superconductor, ISBN 978-953-307-107-7, published by Sciyo (2010).
3. S. Aminorroaya, "Effect of titanium addition to low carbon, low manganese steels on sulphide precipitation", Publisher: VDM Verlag Dr. Muller, ISBN-13: 978-3639236590 (2010).

## Refereed Journal Articles

1. S. Aminorroaya, H. K. Liu, Y. Cho, and A. Dahle, "Microstructure and activation characteristics of Mg-Ni alloy modified by multi-walled carbon nanotubes", International Journal of Hydrogen Energy 35, 4144 (2010). (IF: 3.945, ARC ERA Ranking: A)
2. S. Aminorroaya and H. Liu, "Hydrogen storage properties of Mg-Ni Alloy catalysed by multi-walled carbon nanotubes", Materials Science Forum 654-656, 2843 (2010). (IF: N/A, ARC ERA Ranking: C)
3. S. Aminorroaya, A. Ranjbar, H. K. Liu, Y. Cho, and A. K Dahle, "Structural study and hydrogen sorption kinetics of ball-milled samples of cast Mg-10%Ni catalysed by Nb", Ceramic Transactions 224, 17 (2010). (IF: N/A, ARC ERA Ranking: N/A)
4. Y. S. Ang, S. Sultan and C. Zhang, "Nonlinear optical spectrum of bilayer graphene in the terahertz regime", Applied Physics Letters 97(24), 243110 (2010). (IF: 3.554, ARC ERA Ranking: A\*)
5. C. Z. Chen, C. B. Cai, Z. Y. Liu, L. Peng, B. Gao, F. Fan, Y. M. Lu, R. Zeng, Z. P. Guo, W. X. Li and S. X. Dou, "Stress evolution and lattice distortion induced by thickness variation and lattice misfit in  $La_{0.67}Sr_{0.33}MnO_{3-\delta}$ ", Solid State Communications 150(1-2), 66 (2010). (IF: 1.837, ARC ERA Ranking: B)
6. L. Chen, Z. S. Ma and C. Zhang, "Vertical absorption edge and temperature dependent resistivity in semihydrogenated graphene", Applied Physics Letters 96(2), 023107 (2010). (IF: 3.554, ARC ERA Ranking: A\*)
7. Z. X. Cheng, X. L. Wang, H. Y. Zhao and H. Kimura, "Lead-free potassium bismuth titanate thin film with complex Aurivillius layer structure", Journal of Applied Physics 107(8), 084105 (2010). (IF: 2.072, ARC ERA Ranking: A)
8. Z. X. Cheng, X. L. Wang, Y. Du and S. X. Dou, "A way to enhance the magnetic moment of multiferroic bismuth ferrite", Journal of Physics D 43(24), 242001 (2010). (IF: 2.083, ARC ERA Ranking: A)

9. S. L. Chou, J. Z. Wang, D. Wexler, K. Konstantinov, C. Zhong, H. K. Liu and S. X. Dou, "High-surface-area alpha-Fe<sub>2</sub>O<sub>3</sub>/carbon nanocomposite: one-step synthesis and its highly reversible and enhanced high-rate lithium storage", *Journal of Materials Chemistry* 20(11), 2092 (2010). (IF: 4.795, ARC ERA Ranking: A) (Pictured)
10. S. L. Chou, J. Z. Wang, M. Choucair, H. K. Liu, J. A. Stride and S. X. Dou, "Enhanced reversible lithium storage in a nanosize silicon/graphene composite", *Electrochemistry Communications* 12(2), 303 (2010). (IF: 4.243, ARC ERA Ranking: A)
11. S. L. Chou, Y. Zhao, J. Z. Wang, Z. X. Chen, H. K. Liu and S. X. Dou, "Silicon/single-walled carbon nanotube composite paper as a flexible anode material for lithium ion batteries", *Journal of Physical Chemistry C* 114(37), 15862 (2010). (IF: 4.224, ARC ERA Ranking: A\*)
12. S. L. Chou, J. Z. Wang, H. K. Liu, and S. X. Dou, "Electrochemical deposition of porous VO<sub>x</sub> and MnO<sub>2</sub> nanowires on stainless steel mesh for flexible supercapacitors", *Advanced Science Letters* 3(3), 295 (2010). (IF: N/A, ARC ERA Ranking: N/A)
13. E. Constable, J. Horvat and R. A. Lewis, "Mechanisms of x-ray emission from peeling adhesive tape", *Applied Physics Letters* 97(13), 131502 (2010). (IF: 3.554, ARC ERA Ranking: A\*)
14. G. D. Du, C. Zhong, P. Zhang, Z. P. Guo, Z. X. Chen and H. K. Liu, "Tin dioxide/carbon nanotube composites with high uniform SnO<sub>2</sub> loading as anode materials for lithium ion batteries", *Electrochimica Acta* 55(7), 2582 (2010). (IF: 3.325, ARC ERA Ranking: A)
15. G. D. Du, Z. P. Guo, S. Q. Wang, R. Zeng, Z. X. Chen and H. K. Liu, "Superior stability and high capacity of restacked molybdenum disulfide as anode material for lithium ion batteries", *Chemical Communications* 46(7), 1106 (2010). (IF: 5.504, ARC ERA Ranking: A)
16. G. D. Du, Z. P. Guo, P. Zhang, Y. Li, M. B. Chen, D. Wexler and H. K. Liu, "SnO<sub>2</sub> nanocrystals on self-organized TiO<sub>2</sub> nanotube array as three-dimensional electrode for lithium ion microbatteries", *Journal of Materials Chemistry* 20(27), 5689 (2010). (IF: 4.795, ARC ERA Ranking: A)
17. Y. Du, Z. X. Cheng, M. Shahbazi, E. W. Collings, S. X. Dou and X. L. Wang, "Enhancement of ferromagnetic and dielectric properties in lanthanum doped BiFeO<sub>3</sub> by hydrothermal synthesis", *Journal of Alloys and Compounds* 490(1-2), 637 (2010). (IF: 2.135, ARC ERA Ranking: A)
18. Y. Du, Z. X. Cheng, S. X. Dou, M. Shahbazi, and X. L. Wang, "Enhancement of magnetization and dielectric properties of chromium-doped BiFeO<sub>3</sub> with tunable morphologies", *Thin Solid Films* 518, e5 (2010). (IF: 1.727, ARC ERA Ranking: A)



19. Y. Du, Z. X. Cheng, X. L. Wang and S. X. Dou, "Structure, magnetic, and thermal properties of  $\text{Nd}_{1-x}\text{La}_x\text{CrO}_3$  ( $0 \leq x \leq 1.0$ )", Journal of Applied Physics 108(9), 093914 (2010). (IF: 2.072, ARC ERA Ranking: A)
20. Y. Du, Z. X. Cheng, S. X. Dou, X. L. Wang, H. Y. Zhao and H. Kimura, "Magnetic properties of  $\text{Bi}_2\text{FeMnO}_6$ : A multiferroic material with double-perovskite structure", Applied Physics Letters 97(12), 122502 (2010). (IF: 3.554, ARC ERA Ranking: A\*)
21. Y. Du, Z. X. Cheng, S. X. Dou and X. L. Wang, "Effect of chromium substitution on structure and magnetic properties of  $\text{Bi}_2\text{Fe}_4\text{O}_9$ ", Materials Letters 64(20), 2251 (2010). (IF: 1.940, ARC ERA Ranking: B)
22. L. M. Fang, X. T. Zu, C. M. Liu, Z. J. Li, G. Peleckis, S. Zhu, H. K. Liu and L. M. Wang, "Microstructure and magnetic properties in  $\text{Sn}_{1-x}\text{Fe}_x\text{O}_2$  ( $x=0.01, 0.05, 0.10$ ) nanoparticles synthesized by hydrothermal method", Journal of Alloys and Compounds 491(1-2), 679 (2010). (IF: 2.135, ARC ERA Ranking: A)
23. X. P. Fang, X. Lu, X. W. Guo, Y. Mao, Y. S. Hu, J. Z. Wang, Z. X. Wang, F. Wu, H. K. Liu and L. Q. Chen, "Electrode reactions of manganese oxides for secondary lithium batteries", Electrochemistry Communications 12(11), 1520 (2010). (IF: 4.243, ARC ERA Ranking: A)
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26. C. Q. Feng, H. Li, P. Zhang, Z. P. Guo and H. K. Liu, "Synthesis and modification of non-stoichiometric spinel ( $\text{Li}_{1.02}\text{Mn}_{1.90}\text{Y}_{0.02}\text{O}_{4-y}\text{F}_{0.08}$ ) for lithium-ion batteries", Materials Chemistry and Physics 119(1-2), 82 (2010). (IF: 2.015, ARC ERA Ranking: B)
27. J. Foroughi, S. R. Ghorbani, G. Peleckis, G. M. Spinks, G. G. Wallace, X. L. Wang and S. X. Dou, "The mechanical and the electrical properties of conducting polypyrrole fibers", Journal of Applied Physics 107(10), 103712 (2010). (IF: 2.072, ARC ERA Ranking: A)
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31. Y. H. Guo, W. W. Sun, Z. P. Guo, H. K. Liu, D. L. Sun, X. B. Yu, "Dehydrogenation promotion of  $\text{LiBH}_4$  center dot  $\text{NH}_3$  through heating in ammonia or mixing with metal hydrides", Journal of Physical Chemistry C 114(29), 12823 (2010). (IF: 4.224, ARC ERA Ranking: A\*)
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33. M. F. Hassan, Z. P. Guo, Z. Chen and H. K. Liu, "Carbon-coated  $\text{MoO}_3$  nanobelts as anode materials for lithium-ion batteries", Journal of Power Sources 195(8), 2372 (2010). (IF: 3.792, ARC ERA Ranking: B)
34. M. F. Hassan, M. M. Rahman, Z. P. Guo, Z. X. Chen and H. K. Liu, " $\text{SnO}_2$ - $\text{NiO}$ -C nanocomposite as a high capacity anode material for lithium-ion batteries", Journal of Materials Chemistry 20(43), 9707 (2010). (IF: 4.795, ARC ERA Ranking: A)
35. M. F. Hassan, M. M. Rahman, Z. P. Guo, Z. X. Chen and H. K. Liu, "Solvent-assisted molten salt process: A new route to synthesise alpha- $\text{Fe}_2\text{O}_3/\text{C}$  nanocomposite and its electrochemical performance in lithium-ion batteries", Electrochimica Acta 55(17), 5006 (2010). (IF: 3.325, ARC ERA Ranking: A)
36. M. Ismail, Y. Zhao, X. B. Yu and S. X. Dou, "Effects of  $\text{NbF}_5$  addition on the hydrogen storage properties of  $\text{LiAlH}_4$ ", International Journal of Hydrogen Energy 35(6), 2361 (2010). (IF: 3.945, ARC ERA Ranking: A)

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43. H. Liu, J. Park and G. X. Wang, "Nanosize  $SnO_2$  for highly responsive gas sensor application", Sensor Letters 8(2), 243 (2010). (IF: 0.626, ARC ERA Ranking: C)
44. H. K. Liu, Z. P. Guo, J. Z. Wang and K. Konstantinov, "Si-based anode materials for lithium rechargeable batteries", Journal of Materials Chemistry 20(45), 10055 (2010). (IF: 4.795, ARC ERA Ranking: A)
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135. A. V. Pan, S. V. Pysarenko, and S. X. Dou, "A pinning model and universal pinning regimes in  $YBa_2Cu_3O_7$  superconducting films", Proceedings of the 9<sup>th</sup> International Conference on Materials and Mechanisms of Superconductivity (Tokyo, Japan), *Physica C* 470, S857 (2010). (IF: 0.723, ARC ERA Ranking: C)
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137. E. M. Pogson, P. E. Metcalfe, and R. A. Lewis, "Analysis of EBT2 gafchromic film using terahertz", Proceedings of the 19<sup>th</sup> Australian Institute of Physics Congress, (Melbourne, Australia), 2010. (IF: N/A, ARC ERA Ranking: N/A)
138. S. V. Pysarenko, A. V. Pan, S. X. Dou and R. Nigam, "Extended dislocation-based pinning mechanism in superconducting  $YBa_2Cu_3O_7$  films", Proceedings of the 11<sup>th</sup> Joint MMM-Intermag Conference (Washington DC, USA), *Journal of Applied Physics* 107(9), 09E118 (2010). (IF: 2.072, ARC ERA Ranking: A)

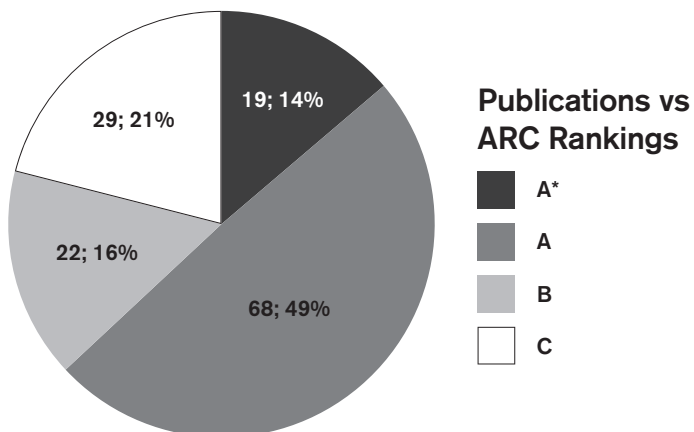
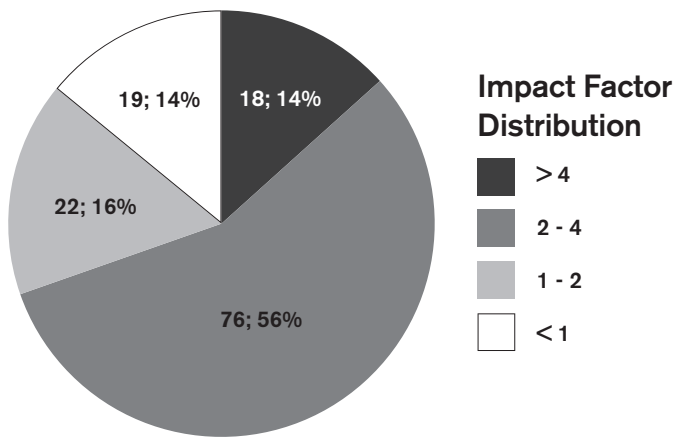
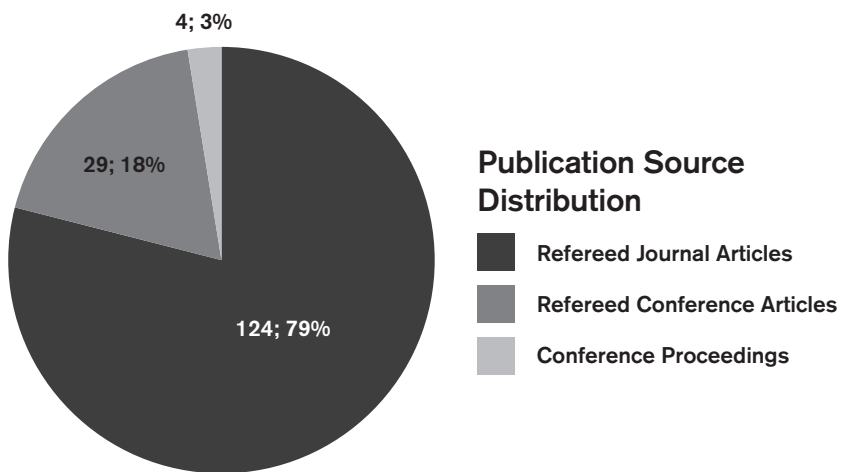
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140. H. S. Ryu, J. S. Kim, Z. P. Guo, H. K. Liu, K. W. Kim, J. H. Ahn and J. H. Ahn, "Electrochemical properties of Fe<sub>2</sub>O<sub>3</sub> thin film fabricated by electrostatic spray deposition for lithium-ion batteries", Proceedings of the 3<sup>rd</sup> International Symposium on Functional Materials/Advances in Functional Materials Conference (Jinju City, South Korea), Physica Scripta T139, 014066 (2010). (IF: 0.723, ARC ERA Ranking: B)
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142. P. Shamba, R. Zeng, J. Q. Wang, and S. X. Dou, "A sign of field-induced first order magnetic state transition and giant reversible magnetocaloric effect in cobalt hydroxide nanosheets", Proceedings of the 11<sup>th</sup> Joint MMM-Intermag Conference (Washington DC, USA), Journal of Applied Physics 107(9), 09A919 (2010). (IF: 2.072, ARC ERA Ranking: A)
143. A. V. Shcherbakov, J. Horvat, O. V. Shcherbakova, N. Novosel, E. Babic, and S. X. Dou, "Temperature effect on microstructure and electromagnetic performance of polycrystalline and sugar-doped MgB<sub>2</sub> wires" Journal of Applied Physics Conference Series 234, 022033 (2010). (IF: N/A, ARC ERA Ranking: N/A)
144. O. V. Shcherbakova, A. V. Pan, S. X. Dou, R. Nigam and D. Wexler, "Nanocoating of particles for optimal doping and universal enhancement of current-carrying ability in "organic" MgB<sub>2-x</sub>C<sub>x</sub> superconductors", Proceedings of the 11<sup>th</sup> Joint MMM-Intermag Conference (Washington DC, USA), Journal of Applied Physics 107(9), 09E147 (2010). (IF: 2.072, ARC ERA Ranking: A)
145. O. V. Shcherbakova, A. V. Pan, E. Babic, and S. X. Dou "Organic" MgB<sub>2-x</sub>C<sub>x</sub> superconductor with high performance enabled by liquid mixing approach" Journal of Applied Physics Conference Series 234, 012038 (2010). (IF: N/A, ARC ERA Ranking: N/A)
146. O. V. Shcherbakova, A. V. Pan, S. Fedoseev, S. X. Dou, S. K. H. Lam, J. Du, and C. P. Foley, "Multilayered approach to step-edge Josephson junctions", Proceedings of the 7<sup>th</sup> Pacific Rim International Conference on Advanced Materials and Processing (Cairns Australia), Materials Science Forum 654-656, 1836 (2010). (IF: N/A, ARC ERA Ranking: C)
147. A. Y. Shenouda and H. K. Liu, "Preparation, characterization, and electrochemical performance of Li<sub>2</sub>CuSnO<sub>4</sub> and Li<sub>2</sub>CuSnSiO<sub>6</sub> electrodes for lithium batteries", Proceedings of the Austria Meeting-of-the-Society (Vienna, Austria), Journal of the Electrochemical Society 157(11), A1183 (2010). (IF: 2.241, ARC ERA Ranking: A)
148. D. Q. Shi, X. B. Xu, X. B. Zhu, L. Wang, Q. Li, and S. X. Dou, "Step phenomenon of vortices flow in superconductor", Proceedings of the 9<sup>th</sup> International Conference on Materials and Mechanisms of Superconductivity (Tokyo, Japan), Physica C 470, S836 (2010). (IF: 0.723, ARC ERA Ranking: C)
149. J. L. Wang, S. J. Campbell, O. Tegus, E. Brück, and S. X. Dou, "Magnetic phase transition in MnFeP<sub>0.5</sub>As<sub>0.4</sub>Si<sub>0.1</sub>", Proceedings of the International Conference on the Applications of the Mössbauer Effect (ICAME 2009), Journal of Physics: Conference Series 217, 012132 (2010). (IF: N/A, ARC ERA Ranking: N/A)
150. J. L. Wang, S. J. Campbell, A. J. Studer, S. J. Kennedy, and R. Zeng, "Magnetic properties of Ho<sub>2</sub>Fe<sub>17-x</sub>Mn<sub>x</sub> – influence of Mn substitution", Proceedings of the International Conference on Magnetism (ICM 2009), Journal of Physics: Conference Series 200, 082025 (2010). (IF: N/A, ARC ERA Ranking: N/A)

151. L. Wang, D. Q. Shi, X. B. Zhu, Q. Li, T. Yamashita, R. Taylor, J. Barry, and S. X. Dou, "Ethanol-based TFA-MOD method for preparation of YBCO films", Proceedings of the 9<sup>th</sup> International Conference on Materials and Mechanisms of Superconductivity (Tokyo, Japan), *Physica C* 470, S1016 (2010). (IF: 0.723, ARC ERA Ranking: C)
152. V. V. Yurchenko, A. J. Qviller, P. B. Mozhaev, J. E. Mozhaeva, J. B. Hansen, C. S. Jacobsen, I. M. Kotelyanskii, A. V. Pan and T. H. Johansen, "Anisotropic currents and flux jumps in high- $T_c$  superconducting films with self-organized arrays of planar defects", Proceedings of the 6<sup>th</sup> International Conference on Vortex Matter in Nanostructured Superconductors (Rhodes, Greece), *Physica C* 470(19), 799 (2010). (IF: 0.723, ARC ERA Ranking: C)
153. R. Zeng, S. Zhou, L. Lu, W. X. Li, and S. X. Dou, "Synthesis and characteristics of  $MgB_2$  bulks with different densities", Proceedings of the 9<sup>th</sup> International Conference on Materials and Mechanisms of Superconductivity (Tokyo, Japan), *Physica C* 470, S669 (2010). (IF: 0.723, ARC ERA Ranking: C)
154. C. Zhong, J. Z. Wang, Z. Z. Zhu, S. L. Chou, Z. X. Chen, Y. Li and H. K. Liu, "Hydrothermal synthesis of nanostructured  $MnO_2$  under magnetic field for rechargeable lithium batteries", Proceedings of the Symposium on Nanostructured Materials for Electrochemical Energy Systems - Lithium Batteries, Supercapacitors and Fuel Cells (Singapore, Singapore), *Journal of Solid State Electrochemistry* 14(10), 1743 (2010). (IF: 1.821, ARC ERA Ranking: C)
155. S. H. Zhou, Y. Zhang, and S. X. Dou, "Effects of  $B_2O_3$  in precursor B powder on  $MgB_2$  critical current density", Proceedings of the 9<sup>th</sup> International Conference on Materials and Mechanisms of Superconductivity (Tokyo, Japan), *Physica C* 470, S635 (2010). (IF: 0.723, ARC ERA Ranking: C)

## Patents

156. S. X. Dou, H. K. Liu, A. V. Pan, S. H. Zhou, and M. H. Ionescu, "Method of synthesis of a superconducting material", U. S. Patent 7,838,465 B2 (2010).

## Publication Statistics



# Funding 2010

## Australian Research Council Grants

### ARC Centre of Excellence Grants

Chief Investigators	Title	2010 Funding
H. K. Liu	Nano-materials for energy storage	\$230,000
<b>Total</b>		<b>\$230,000</b>

### ARC Discovery Scheme Grants

Chief Investigators	Title	2010 Funding
S. X. Dou, J. Driscoll, R. L. Flukiger, H. Kumakura, M. D. Sumpston	Current limiting mechanisms in magnesium diboride superconductors	\$180,000
Z. P. Guo	Charge transfer mechanism in 3-dimensional pore-solid nanoarchitectures for electrochemical systems	\$100,000
G. Peleckis	Development of novel high efficiency thermoelectric oxides for high temperature power generation	\$35,000
S. H. Zhou	Fabrication of high quality MgB <sub>2</sub> superconductor	\$40,000
S. X. Dou, J. H. Kim, T. H. Johansen, E. Bruck	Giant magnetocaloric materials and room temperature refrigeration	\$120,000
X. B. Yu	Improvement and synthesis of advanced hydrogen storage materials for fuel cell application	\$96,000
C. Zhang, D. Li, F. Liu, R. B. Kaner, Y. Jiang	Novel graphene nanostructures: modelling, synthesis, fabrication and characterization	\$145,000
A. V. Pan, C. P. Foley, T. H. Johansen, H. Hilgenkamp	Tailoring superconducting hybrid multilayered film systems for electric and electronic applications	\$159,000
X. L. Wang, Z. X. Cheng, D. P. Chen, T. Kimura, F. Klose	Frustrated magnets: a new platform for multiferroic materials	\$115,000
R. A. Lewis, J. Horvat, W. Xu	Better emitters, enhanced optics, superior detectors: advancing terahertz science and technology for applications in medicine, agriculture, industry and national security	\$90,000
J. Z. Wang	Development of inorganic-conducting polymer composites and ionic liquid based electrolytes for rechargeable lithium batteries	\$110,000
Z. P. Guo, Z. Chen, J. Dahn, J. Chen	New directions to miniaturized power sources: integrated all-solid-state rechargeable batteries	\$135,000
J. H. Kim, Y. Zhao, X. Zhu, Z. Sun	Directed assembly and photoelectric properties of core-shell nanowire networks of PbSe-TiO <sub>2</sub> heterostructures for high efficiency low-cost solar cells	\$100,000
K. Konstantinov, H. K. Liu, A. Calka, D. Wexler	Advanced nanostructured ceramic composites for ultracapacitors	\$90,000
X. L. Wang, G. Peleckis, D. P. Chen, H. Hosono, X. Chen, K. H. Muller, E. Muromachi, A. J. Studer	Materials science and superconductivity in the new Fe-based high temperature superconductors	\$155,000
<b>Total</b>		<b>\$1,670,000</b>

## ARC Future Fellowship

Chief Investigators	Title	2010 Funding
Z. X. Cheng	Manipulation of spin by electric field	\$172,000
<b>Total</b>		<b>\$172,000</b>

## ARC Linkage Projects

Chief Investigators	Title	2010 Funding
A. V. Pan, S. X. Dou, O. Mukhanov	Development of superconducting leads with ultra-low thermal conductivity for cryoelectronic applications	\$146,000
C. Zhang, X. L. Wang, G. X. Wang, T. Toyoda	Novel methods for enhancing room temperature figure of merit of thermoelectric/thermionic materials for refrigeration applications	\$87,000
Z. P. Guo, H. K. Liu, C. D. Cook, D. Wexler, H. Zhu, X. J. Zhu	Development of advanced lithium ion battery and battery management system for electric/hybrid electric vehicle applications	\$80,000
S. X. Dou, X. L. Wang, C. D. Cook, X. Xu, E. W. Collings, J. Yoo	Magnesium diboride superconductor magnets for applications	\$100,000
S. X. Dou, J. Horvat, X. Xu, J. W. Moscrop	Design, build and test a fault current limiter employing magnesium diboride (MgB <sub>2</sub> ) superconducting coils	\$195,000
J. Z. Wang, H. K. Liu, K. K. Konstantinov, Z. X. Wang	Room temperature rechargeable sulphur batteries	\$70,000
<b>Total</b>		<b>\$678,000</b>

## ARC Linkage International Awards/Fellowships

Chief Investigators	Title	2010 Funding
S. X. Dou, Y. Zhao, X. X. Xi, G. Ramanath, Q. J. Li, G. Peleckis	Approved development of nano-structured thermoelectric materials for power generation from heat	\$20,000
X. L. Wang, S. Lee	Mechanism and enhancement of supercurrent carrying ability in magnesium diboride superconductor	\$18,000
<b>Total</b>		<b>\$38,000</b>

## ARC Linkage Infrastructure, Equipment and Facilities (LIEF)

Chief Investigators	Title	2010 Funding
S. X. Dou, G. Peleckis, A. Rozenfeld, G. Alici, M. Walker, R. Zheng, S. Ringer, S. Li, I. Low, M. Jacob, E. Pereloma, J. Nowotny, H. K. Liu, C. Stampfl, R. Ramer, M. in het Panhuis, R. Lewis, A. V. Pan, M. Gu, Y. Chen, X. L. Wang, R. Stamps, S. Kennedy, F. Klose, S. Smith, G. Wallace	Combined scanning tunnelling microscope system for materials characterisation and manipulation at nano scale	\$600,000
<b>Total</b>		<b>\$600,000</b>

**2010 Australian Research Council Grants Total**

**\$3,388,000**

## Other Grants

### DIISR International Science Linkage Projects

Chief Investigators	Title	2010 Funding
C. Zhang, R. A. Lewis, X. L. Wang, D. Li	High performance nanomaterials for thermionics and thermoelectric applications	\$73,000
C. Zhang, R. A. Lewis, J. Horvat, R. Vickers, W. Xu, J. Xi	Development of terahertz emitters based on electronic and hybrid spintronic materials	\$50,000
<b>Total</b>		<b>\$125,000</b>

### URC Small Grants & ARC Near-Miss Grants

Chief Investigators	Title	2010 Funding
Z. X. Cheng	Doped BiFeO <sub>3</sub> thin film on piezoelectric substrates for robust room temperature magnetocaloric coupling	\$13,000
X. B. Yu	Design and synthesis of ammonia-borane complexes with high hydrogen capacity	\$10,000
Y. Zhao	Surface modification of titanium and titanium alloys for medical device applications	\$9,000
K. Konstantinov	Application of functionalised nanoceramics for protection from radiation and oxidative stress related disorders	\$8,000
<b>Total</b>		<b>\$40,000</b>

### URC RIBG Pool 2

Chief Investigators	Title	2010 Funding
Y. Zhao, H. K. Liu, S. Aminorroaya, Z. P. Guo, J. Z. Wang, S. X. Dou, X. B. Yu, J. Chen, A. Calka, R. A. Lewis, K. Konstantinov, R. Dippenaar	Residual gas analysis system to be connected with TGA	\$65,000
<b>Total</b>		<b>\$65,000</b>

**UOW Support (Performance, Management, PGS Maintenance)**

**\$302,000**

**Total Funding 2010**

**\$3,920,000**

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