ISEM 2015
Annual Report

INSTITUTE *for* SUPERCONDUCTING *and* ELECTRONIC MATERIALS

UNIVERSITY OF WOLLONGONG AUSTRALIA

Contents

Cover: A superconducting fault current limiter

Director's Report

Dear All,

ISEM had a very successful year in 2015. For your information, I would like to briefly highlight some of our achievements.

ISEM has made significant advances and breakthroughs in energy storage materials, topological, thermoelectric, solar, and catalytic materials, superconductors, as well as in THz science and photonics. We have continued our breakthrough work on silicene, a single atom thick layer of silicon. Scanning tunneling microscopy (STM) observations suggest that the "multilayer silicene" is indeed a bulk-like Si(111) film with a $(\sqrt{3} \times \sqrt{3})R30°$ honeycomb superstructure on surface. On this surface, delocalized surface state as well as linear energy-momentum dispersion was observed from quasiparticle interference patterns. Our results indicate that a bulklike silicon film with diamondlike structure can also host delocalized surface state, which is even more attractive for potential applications, such as new generation of nanodevices based on Si. Our investigations on YBCO superconducting thin films that vortex distribution shows a weak short-range positional order, while Delaunay triangulation shows a near-complete lack of orientational order. The distribution of these vortices is finally characterised as an isotropic vortex glass. In energy storage materials, uniform yolk-shell iron sulfide–carbon nanospheres have been synthesized as cathode materials for the emerging sodium sulfide battery to achieve remarkable capacity of ~545 mAh g^{-1} over 100 cycles at 0.2 C (100mAg^{-1}), delivering ultrahigh energy density of ~438Whkg^{-1}. We have developed fish-scale bio-inspired multifunctional ZnO nanostructures that have similar morphology and structure to the cycloid scales of the Asian Arowana. These nanostructured coatings feature tunable light refraction and reflection, modulated surface wettability and damage-tolerant mechanical properties. Such nanostructures are promising for applications in (i) optical coatings, sensing or lens arrays for use in reflective displays, packing, advertising and solar energy harvesting; (ii) self-cleaning surfaces, including anti-smudge, anti-fouling and anti-fogging, and self-sterilizing surfaces; and (iii) mechanical/chemical barrier coatings.

Innovation and research collaboration has been ISEM's central theme for past 20 years and 2015 has been a true testament to that. The last three years of ISEM's participation in Auto CRC ($3.5 million, 7 projects) as program leader set an excellent example of the innovation and collaboration with industry partners, which lead to significant breakthroughs and advances in key research areas. These, in turn, resulted in further success in securing $4.7 million ARENA funding dedicated to the development of smart sodium storage system, sponsored by five industry partners. Other major projects with industry partners included a Coal Service Association grant of $670,000 and $1.4M project with Valley Longwall International, concentrating on the development of diesel free electric vehicles for Australian mines.

Our research excellence is evidenced by outstanding publication data. In 2015, ISEM published 244 papers, with 27 of these papers appearing in journals with IF > 10, including two in Nature Communications. Papers published in 2015 contributed one third, of UOW's total self-exclusive citations, a 32% increase compared to 28% in 2014 and 61% increase compared to 23% in 2013. Nine of the top 10 most cited papers from UOW are from ISEM. It is evident, that such a rapid increase in citation has made a major impact on the UOW QS and ERA ranking. The citation per faculty is the only factor that increased from 394th in 2014 to 195th in 2015. This resulted in UOW ranking to increase from 283rd in 2014 to 243rd in 2015 and from 26th to 17th position for "under 50 years" universities, while other five factors were either unchanged or even decreased.

The research excellence has also led to the success in ARC grants. ISEM won 2 DP, 2 Future Fellowships, 1 DECRA, and one LIEF totalling $3.482M, contributing **36%** of UOW total in these categories ($8.507M). ISEM members also participated in another large LIEF ($980k) grant lead by UOW. We have also won a grant of $250k on energy storage from Korean Government.

19 PhD students have graduated in 2015, bringing our total ISEM PhD completion to 144 who are widely distributed within five continents. Many were promoted to senior level and 3 recent graduates were appointed as Professors in highly regarded universities in China. Our students have won the 3 min thesis competition, EMC presentation competition, Chinese Government private students scholarship award (total 18 in the past 9 years) and 6 PhD students won ISEM excellence, merit and thesis awards.

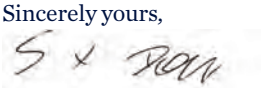
Our academic staffs have further enhanced their international reputation as evidenced by their appointment as Honorary Professors, Members of Editorial Boards, and Advisory Boards at prestigious universities and journals. By now ISEM has won 57 ARC fellowships, more than **40%** of UOW total during the same period. Two members were promoted to Professor, one to Associate Professor, and two to Senior Researchers. Several early career researchers have established their leadership in their fields.

ISEM has further extended its international collaborative network, ranging from individual partnerships to UOW-BUAA joint centre and NIMS. More than **60%** of our publications are in collaboration with international institutions.

I would like to take this opportunity to sincerely acknowledge the strong support ISEM has received throughout the year from UOW Executives, faculty, admin staff, technical staff, OHS staff, commercial management staff, industry partners, and academic collaborators. I would also like to express my gratitude to ISEM staff, students, honorary professors, and visitors for their dedication and hard work.

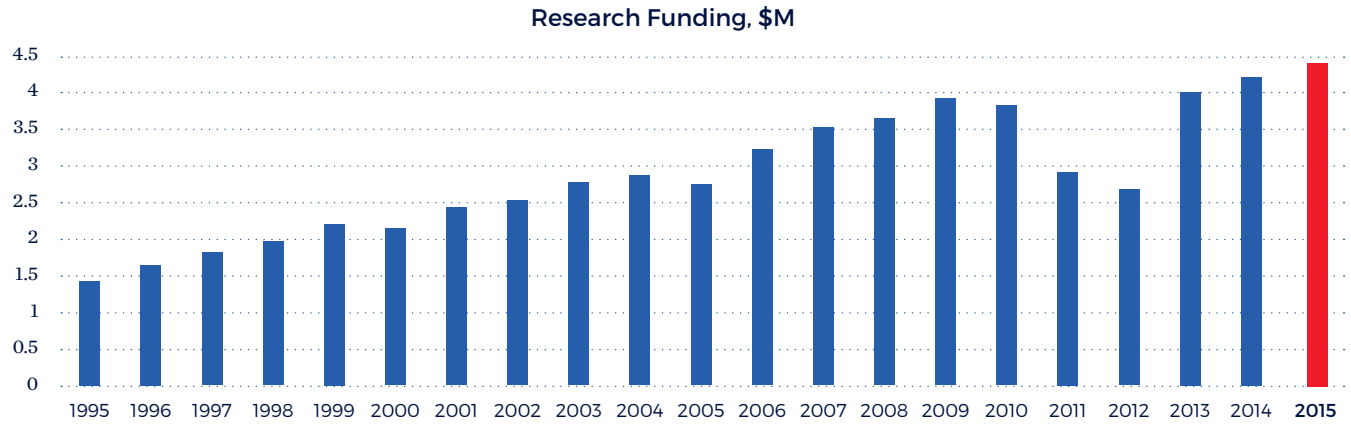
I am certain that ISEM will continue its success across the board in 2016 and significantly contribute towards UOW's aspirational goal of reaching top 1% of universities worldwide.

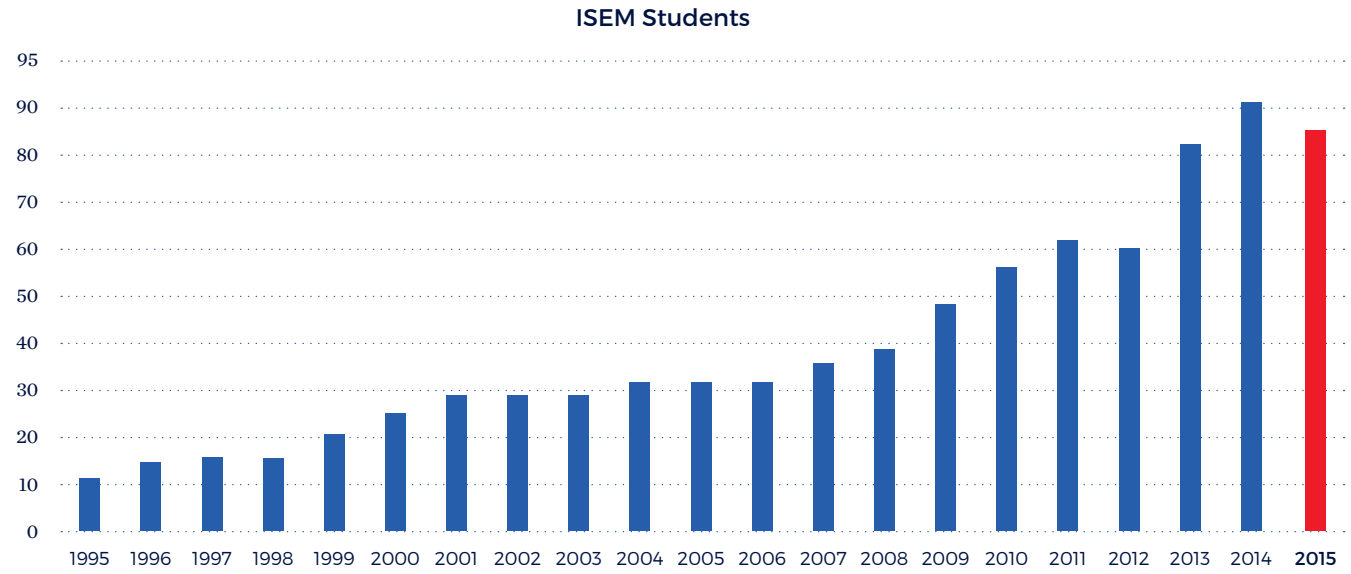
Sincerely yours,

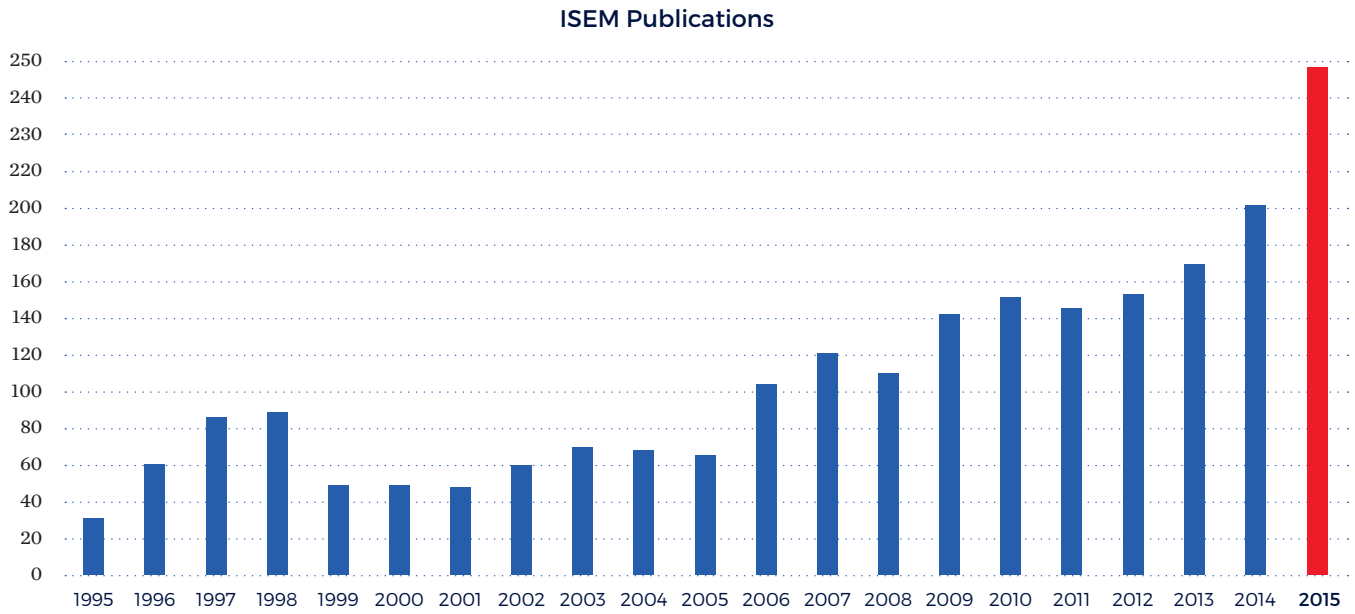


Prof. Shi Xue Dou

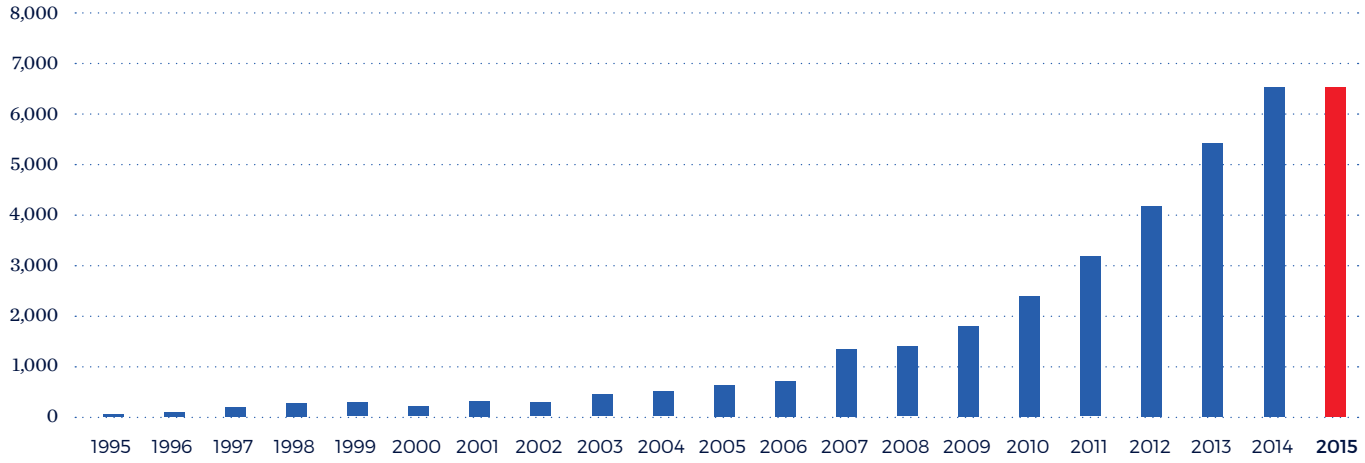
ISEM at a glance



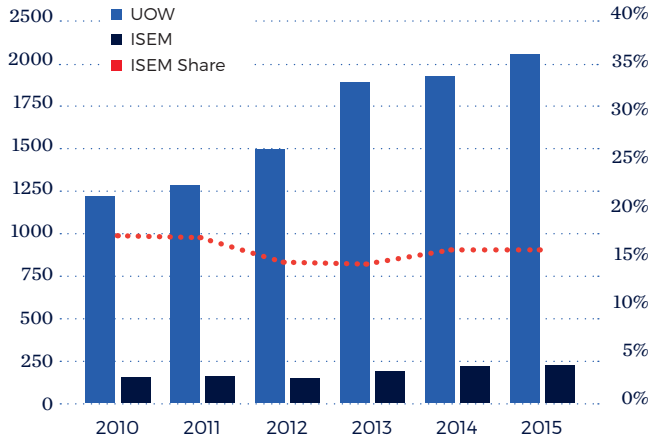




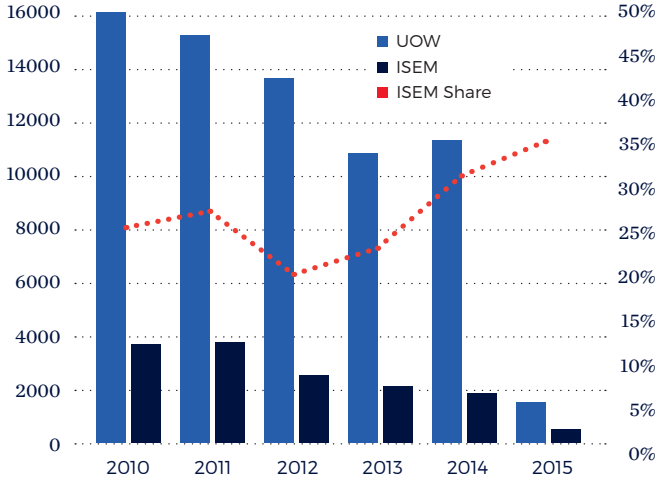
ISEM Publications - Citations



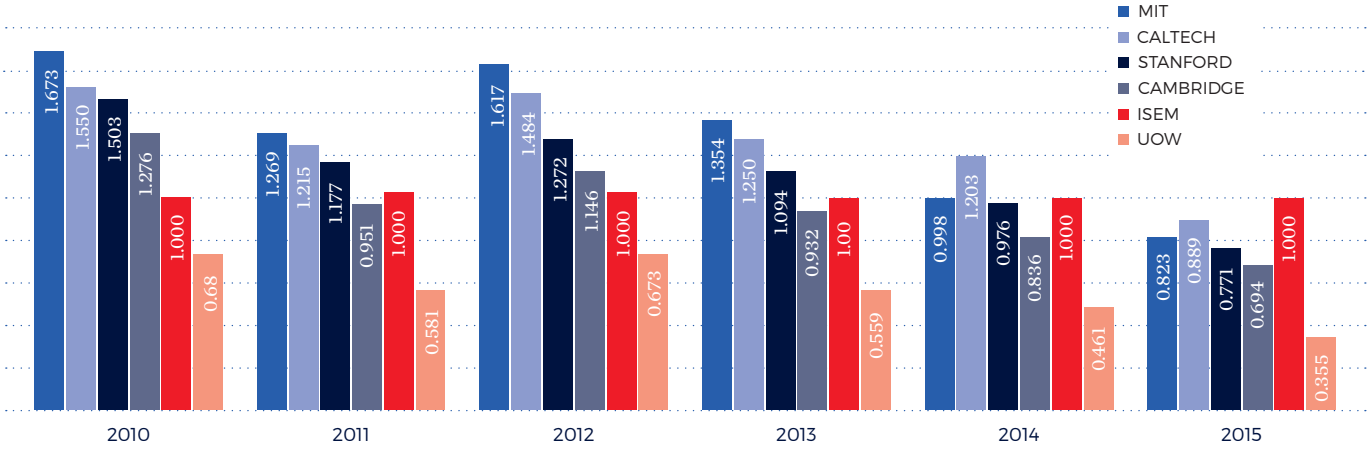
ISEM vs UOW Publications 2010–2015



ISEM vs UOW Citations 2010–2015



Citations per paper 2010-2015 (accumulated)
World top 4 vs ISEM/UOW
[Normalised to ISEM]



Signing of the Memorandum of Understanding between University of Wollongong and National Institute for Materials Science (NIMS), Japan

Management

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	Dr. Germanas Peleckis	Assistant Director, ISEM

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Dr. Ziqi Sun (BSc, MSc, PhD, ARC Postdoctoral Fellow)
Dr. Sima Aminorroaya-Yamini (BSc, MSc, PhD, ARC DECRA Fellow)
Dr. Zhenguo Huang (BSc, MSc, PhD, ARC DECRA Fellow)
Dr. Md Shahriar Hossain (BSc, PhD, ARC DECRA Fellow)
Dr. Zongqing Ma (BSc, PhD, ARC DECRA Fellow)

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Prof. Shane Kennedy, Deputy Director of Bragg Institute, ANSTO
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Prof. Zhong Fan Liu, University of Pecking, Beijing, P. R. China
Prof. Liming Dai, Case Western Reserve University, USA

Current and Ongoing Research Projects

ARC DISCOVERY PROJECTS

Electron and spin transport in topological insulators

Years Funded:	2013 $120,000	2014 $150,000	2015 $140,000
Total Funding:	$410,000		
Project ID:	DP130102956		
Chief Investigators:	X. L. Wang, C. Zhang, R. A. Lewis,		
Partner Investigator:	Q. K. Xue, A. Hoffmann, F. Klose		
Project Summary:	This project brings together experts with complementary skills to study newly discovered topological insulators that conduct electricity on their surface but not inside. The project will explore potential applications of this new class of materials in novel electronics, optics, spintronics, superconducting and quantum information technologies.		

Nanostructure engineering of semiconductor nanowires for high performance thermoelectrics

Years Funded:	2013 $110,000	2014 $100,000	2015 $100,000
Total Funding:	$310,000		
Project ID:	DP130102699		
Chief Investigators:	Z. Li, G. M. Lu		
Partner Investigator:			
Project Summary:	This project aims to develop high-performance thermoelectric semiconductor nanowires for recovery of waste heat from automotive exhausts and industrial processes. The successful development of such technology would help save energy, reduce carbon emissions and create enormous economic and environmental benefits for Australia and the world.		

Novel terahertz electronics, photonics and plasmonics in high-mobility, low-dimensional electronic systems (HMLDES)

Years Funded:	2014 $130,000	2015 $140,000	2016 $140,000
Total Funding:	$410,000		
Project ID:	DP140101501		
Chief Investigators:	C. Zhang, X. L. Wang, R. A. Lewis, Q. L. Bao, J. Horvat		
Partner Investigator:			
Project Summary:	High-mobility, low-dimensional electronic systems (HMLDES) are of importance in developing the next generation of electronics, photonics and plasmonics. This is due to their very rapid response time and their strong coupling with the electromagnetic field. This project will investigate the electronic and optical properties of HMLDES in the terahertz frequency regime in a search for a new mechanisms leading to terahertz emission and detection. This fundamental research on charge dynamics, plasmonics and non-linear optical processes in HMLDES will link electronics and optics, paving the way for new HMLDES-based terahertz electronic, photonic and plasmonic devices that will significantly expand terahertz technology to the benefit of all Australians.		

Lithium-ion air batteries with non-flammable ionic liquid–based electrolytes

Years Funded:	2014	2015	2016
	$55,000	$140,000	$155,000
Total Funding:	$350,000		
Project ID:	DP140100401		
Chief Investigators:	J. Z. Wang, J. Chen, S. L. Chou, H. K. Liu, H. S. Zhou, X. L. Wang		
Partner Investigator:			
Project Summary:	The aim of this project is to develop rechargeable lithium-ion air batteries based on novel advanced materials and non-flammable ionic-liquid-based electrolytes for use in electric vehicles. The success of this project would make a significant contribution to improving the safety of typical lithium-air batteries. The expected outcomes include: establishing novel lithium-ion air battery electrochemical systems using selected advanced electrode materials and electrolytes which are developed in this proposal; and, understanding the degradation mechanisms of electrode materials in the novel lithium-ion air battery systems with different advanced optimized fabrication methods.		

Design and exploration of novel p-block materials for solar energy conversion

Years Funded:	2014	2015	2016
	$215,000	$145,000	$160,000
Total Funding:	$520,000		
Project ID:	DP1402581		
Chief Investigators:	S. X. Dou, Y. Du, X. Xu, G. Peleckis, J. Scott, J. H. Ye, W. C. Hao, K. S. Liu, P. Cheng		
Partner Investigator:			
Project Summary:	This project aims to design and explore novel visible light p-block photocatalysts through in depth surface studies of materials at an atomic level. A new strategy of band structure engineering and in-situ investigation of atomiclevel photocatalytic dynamics will be the key elements in this research which is expected to yield several novel visible light photocatalysts. The outcome of the project will be the understanding of processes and mechanisms underlying the photocatalysis and building the foundation of usable, stable, and durable visible-light photocatalytic applications.		

Development of highly regenerable ammonia-borane and related boron nitride-based hydrides with low cost for hydrogen storage

Years Funded:	2014	2015	2016
	$110,000	$115,000	$120,000
Total Funding:	$345,000		
Project ID:	DP140102858		
Chief Investigators:	Z. P. Guo, Z. G. Huang, H. K. Liu, X. B. Yu, Q. F. Gu		
Partner Investigator:			
Project Summary:	The project will design and synthesise novel boron-nitrogen hydrides. It will employ material design strategies, such as new synthesis techniques, dopant destabilisation, and dehydrogenation catalysts to design and experimentally validate novel multicomponent hydride systems with high storage capacities (above 9 wt% under near-ambient conditions) and high reversibility. The outcomes of this project will make a significant enhancement in the performance of solid state hydrogen storage materials and will deliver a viable storage technology for a range of fuel cell applications.		

FUTURE FELLOWSHIPS

Development of a solid nitrogen cooled magnesium diboride (MgB_2) magnet for persistent mode operation

Years Funded:	2011 $86,000	2012 $172,000	2013 $172,000	2014 $172,000	2015 $86,000

Total Funding: $688,000

Project ID: FT110100170

Chief Investigators: J. H. Kim

Project Summary: Soaring price for liquid helium has increased demand for cryogen-free superconducting magnets more than ever. If magnetic resonance imaging magnets, which represent over 50 per cent of the world superconducting markets, could be operated without liquid helium, magnetic resonance imaging would be much more affordable and enable reduced health care costs.

Electronic topological materials

Years Funded:	2013 $124,000	2014 $247,000	2015 $246,000	2016 $246,000	2017 $124,000

Total Funding: $987,000

Project ID: FT130100778

Chief Investigators: X. L. Wang

Project Summary: Discovery of new classes of materials with new functionalities or significantly improved performance has always been the driving force for the advance of modern science and technology, and the improvement of our daily lives. This project aims to discover a number of innovative materials, based on new strategies of materials design, discover their novel functionalities and novel quantum effects, and elucidate their underlying physics. It is expected that these novel materials will provide a new platform for superconductivity, magnetism, spintronics, optical and multi-disciplinary sciences, and lead to future generations of advanced multifunctional electronic devices.

Lead-free bismuth based dielectric materials for energy storage

Years Funded:	2014 $111,000	2015 $222,000	2016 $222,000	2017 $222,000	2018 $111,000

Total Funding: $888,000

Project ID: FT140100698

Chief Investigator: S. J. Zhang

Project Summary: Electrical energy generation from renewable sources, such as solar, wind and geothermal, provide enormous potential for meeting future energy demands. However, the ability to store and control this energy for miniaturisation and modularisation in applications requiring a wide temperature usage range is a limiting factor that needs to be addressed. This project aims to develop new bismuth-based lead-free dielectric materials for improving the storage density of high temperature multilayer ceramic capacitors for sustainable applications in the energy and vehicle industries, where high temperature stability and high volumetric efficiency are crucial.

DECRA FELLOWSHIPS

Rational design of a new generation magnesium diboride superconducting rotor coil suitable for offshore low-cost wind turbine generators

Years Funded:	2013 $125,000	2014 $125,000	2015 $125,000
Total Funding:	$375,000		
Project ID:	DE130101247		
Chief Investigators:	M. S. A. Hossain		
Project Summary:	New developments in wind power technologies provide opportunities in the next decade to deliver renewable energy. The present and future low cost magnesium diboride superconducting technology, coupled with renewable energy sources, has the potential to provide a long-term solution to the energy crisis and global warming threat.		

Nano-engineered, cost-effective lead chalcogenides to boost the performance of mid-range temperature thermoelectric materials

Years Funded:	2013 $125,000	2014 $125,000	2015 $125,000
Total Funding:	$375,000		
Project ID:	DE130100310		
Chief Investigators:	S. Aminorroaya-Yamini		
Project Summary:	This project presents high performance, cost-effective lead-based thermoelectric materials for mid-range temperature thermoelectric generators. The development of these materials for waste heat recovery and solar thermoelectric generators will bring tremendous economic benefits and can have a profound impact on clean alternative energy sources.		

Microstructure design of second generation MgB2 superconducting wires for enhancement of critical current density

Years Funded:	2014 $130,000	2015 $124,000	2016 $124,000
Total Funding:	$377,000		
Project ID:	DE140101333		
Chief Investigators:	Z. Q. Ma		
Project Summary:	Magnesium diboride (MgB_2) superconducting wires have outstanding potential for a diverse range of commercial applications. However, the critical current density in MgB_2 wires is still comparatively low, which represents the biggest obstacle in terms of their practical applications. This project will further enhance the critical current density in second generation MgB_2 wires prepared by an optimized internal magnesium diffusion process through addressing fundamental issues and designing appropriate microstructure. The research outcomes will be extremely beneficial to fundamental research and to the potential application of MgB_2 superconductors. High performing, low-cost second generation MgB_2 wires are also expected to be developed in this project.		

ARC LINKAGE PROJECTS

Development of novel composite anode materials combined with new binders for high energy, high power and long life lithium-ion batteries

Years Funded:	2012	2013	2014	2015
ARC Fund:	$45,000	$90,000	$90,000	$45,000
Inmdustry Fund:	$20,000	$40,000	$40,000	$20,000
Total Funding:	$390,000			
Project ID:	LP100200432			
Chief Investigators:	S. L. Chou, J. Z. Wang, H. K. Liu, D. Wexler			
Partner Investigator:	Y. M. Kang			
Industry Partner:	DLG Battery Co Ltd, Wuxi Xirun Petrochemical			
Project Summary:	This project will lead to better lithium-ion batteries with high energy, high power and long life. Novel composite anode materials combined with new binders will be investigated. The development of new scientific knowledge during this project will significantly enhance the international competitiveness of Australia in the area of clean energy.			

New generation high efficiency thermoelectric materials and modules for waste heat recovery in steelworks

Years Funded:	2012 $60,000	2013 $120,000	2014 $110,000	2015 $80,000	2016 $30,000
Industry Fund:	$70,000	$120,000	$110,000	$80,000	$30,000
Total Funding:	$810,000				
Project ID:	LP100200289				
Chief Investigators:	S. X. Dou, S. Li, W. X. Li, C. Zhang, S. Aminorroaya-Yamini				
Industry Partner:	Baosteel Company				
Project Summary:	The development of thermoelectric materials and devices, and their subsequent uptake by the steel industry, will bring tremendous socio-economic benefits in terms of decreased operational costs, a significantly reduced carbon footprint and will set an excellent example for other industries on how to comply with strict environmental regulations.				

AUTO CRC PROJECTS

Lithium air battery for electric vehicles

Years Funded:	2013 $160,000	2014 $160,000	2015 $160,000
Total Funding:	$480,000		
Project ID:	1-108		
Chief Investigators:	S. X. Dou, G. X. Wang		
Industry Partner:			
Project Summary:	Lithium air batteries have a theoretical density of 11,680 Wh/kg and practically can reach 1700 Wh/kg which is an order of magnitude higher than state-of-the-art LIBs. However, the major challenges of electrochemical stability of both the electrolyte and the cathode must be addressed. This research will seek dramatic improvement of up to an order of magnitude in energy density through a proff-of-concept battery using lithium air technology.		

Design and prototype of on-vehicle battery management system for electric vehicles

Years Funded:	2013 $78,000	2014 $78,000	2015 $78,000
Total Funding:	$234,000		
Project ID:	1-110		
Chief Investigators:	S. X. Dou, Z. P. Guo		
Industry Partner:	Red Arc Co. Ltd.		
Project Summary:	The aim of this project is to develop a battery management system (BMS) for monitoring, balancing, protecting, and optimizing battery modules and pack, as well as hybrid battery/supercapacitor pack to achieve smart charge, optimal performance and cycle life, and high safety.		

Development of advanced electrode and electrolytes for LIB

Years Funded:	2013 $479,000	2014 $479,000	2015 $480,000
Total Funding:	$1,438,000		
Project ID:	1-111		
Chief Investigators:	S. X. Dou, G. X. Wang, H. K. Liu		
Industry Partner:	Malaysia Automotive Institute (MAI)		
Project Summary:	The proposed research program is aimed at achieving major advances in the development of next generation, high energy and high power cathode materials for lithium ion batteries (LIB) with reduced cost and improved safety. The project will concentrate on development of breakthrough scale-up cathode materials; development of liquid/organic ionic or polymer electrolytes with high conductivity and safety; fabricate, test, and evaluate large-size prototypes.		

Battery charge, mechanical and thermal management system development

Years Funded:	2013 $356,000	2014 $356,000	2015 $356,000
Total Funding:	$1,068,000		
Project ID:	1-112		
Chief Investigators:	S. X. Dou, K. W. See		
Industry Partner:	Malaysia Automotive Institute (MAI)		
Project Summary:	The focus of this project is to identify and resolve gaps and weaknesses in EV systems. The project is expected to deliver a fully integrated battery management system module with effective monitoring, charging and balancing capability; reliable and robust mechanical system; a complete vehicle electrification system that is compact, low-cost, easily packaged, and compatible with mass production line for Malaysian automotive industry.		

Lithium ion battery module packaging and testing

Years Funded:	2013 $208,000	2014 $208,000	2015 $208,000
Total Funding:	$624,000		
Project ID:	1-113		
Chief Investigators:	S. X. Dou, K. W. See		
Industry Partner:	Malaysia Automotive Institute (MAI)		
Project Summary:	The battery packs used as rechargeable electrical storage system in electric vehicles are large and complex. Controlled release of the battery's energy provides useful electrical power in the form of current and voltage. However, uncontrolled release of this energy can result in dangerous situations such as release of toxic materials, fire, and high pressure events. These can be best prevented by a properly designed and validated electronic safety and monitoring system. The project will focus on design and development of fully integrated electric vehicle battery packaging system and development of reliable testing platform for electric vehicle battery pack system.		

Thermoelectrics – efficient energy recovery in light and heavy vehicles

Years Funded:	2013 $154,000	2014 $154,000	2015 $154,000
Total Funding:	$464,000		
Project ID:	1-203		
Chief Investigators:	S. X. Dou, S. Aminorroaya-Yamini, Z. Li, G. Peleckis		
Industry Partner:	Baosteel Company		
Project Summary:	The project is targeted in three major directions, i.e. materials, device engineering, and device fabrication with the ultimate goal of the project to achieve high Carnot efficiency for energy conversion from waste heat and at least 2% reduction of fuel consumption in automobiles. This will be achieved through development of novel nano-particle based highly dense thermoelectric materials and design and engineering of new generation thermoelectric modules.		

High energy anode materials for lithium ion batteries

Years Funded:	2015 $13,000	2016 $140,000	2017 $27,000
Total Funding:	$180,000		
Project ID:	1-117		
Chief Investigators:	H. K. Liu, Z. P. Guo, J. Z. Wang, J. H. Kim, K. Konstantinov, S. L. Chou		
Industry Partner:	Baosteel Company		
Project Summary:	The global market for energy storage, including lithium ion batteries (LIBs) for electric vehicles (EVs), will experience unprecedented growth in the next decade. The challenges of EV LIBs are related to the materials used in the LIBs. This project aims to study high energy anode materials with reduced cost and improved safety to meet the requirements for the next generation of LIBs and make them more suitable for EVs.		

The study of carbon based battery materials for Li ion battery

Years Funded:	2013 $33,000	2014 $33,000	2015 $33,000
Total Funding:	$99,000		
Project ID:	4-102		
Chief Investigators:	H. K. Liu, S. X. Dou		
Industry Partner:	Auto CRC		

Sulphur-carbon composite cathode material for Li-S battery

Years Funded:	2013 $33,000	2014 $33,000	2015 $33,000
Total Funding:	$99,000		
Project ID:	4-103		
Chief Investigators:	J. Z. Wang, S. X. Dou		
Industry Partner:	Auto CRC		

Conducting polymer coated graphene oxide nanocomposites for supercapacitor application

Years Funded:	2013 $33,000	2014 $33,000	2015 $33,000
Total Funding:	$99,000		
Project ID:	4-104		
Chief Investigators:	K. Konstantinov, S. X. Dou		
Industry Partner:	Auto CRC		

Fabrication & characterisation of graphene & graphene oxide composites for application in supercapacitors & Li-ion batteries

Years Funded:	2013 $33,000	2014 $33,000	2015 $33,000
Total Funding:	$99,000		
Project ID:	4-105		
Chief Investigators:	Z. P. Guo, S. X. Dou		
Industry Partner:	Auto CRC		

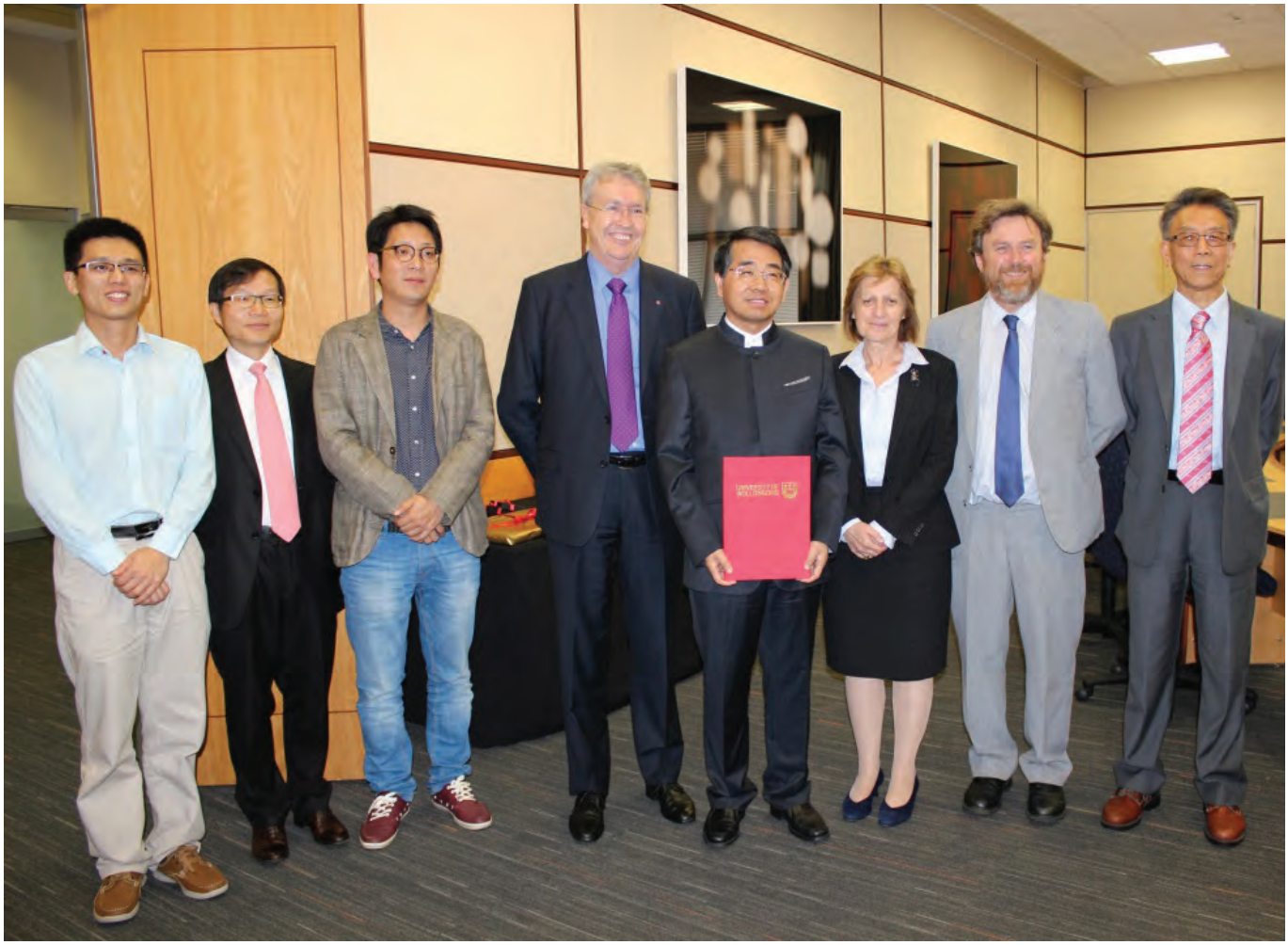
UOW AND OTHER GRANTS

Coal Services – Health and Safety Trust
Diesel-Free Environment for Underground Coal Mines

Years Funded:	2015 $110,000	2016 $110,000	2017 $105,000
Total Funding:	$325,000		
Chief Investigators:	S. X. Dou, K. W. See		
Project Summary:	The potential for adverse health effects arising from occupational exposure to diesel particulate has been the subject of intense scientific debate for the past 25 years. Diesel exhaust (DE) and diesel particulate matter (DPM) in underground mines are a health risk for workers, who can suffer acute and chronic health conditions (e.g. asthma, nausea, lung inflammation, headaches, eye and nose irritation, cardiopulmonary disease, cardiovascular disease, and cancer) through exposure to NOx (nitric oxide and nitrogen dioxide (NO2)). Also, noise levels in the proximity of diesel-vehicle operation – particularly in confined settings –impair the hearing of operators following many hours of exposure. This project takes the stance that from a regulatory perspective emission prevention, not reduction, should be the ultimate policy goal. We aims to remove barriers to the adoption of electric-drive diesel free general purpose vehicles in underground mines, which have clear benefit to Australian mines via lower operating costs and cleaner environments for workers.		

Baosteel Australia Joint Research Centre
High energy anode materials for lithium ion batteries

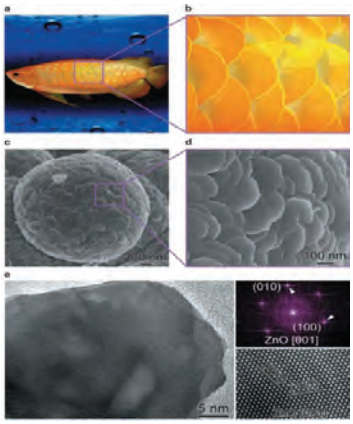
Years Funded:	2015 $100,000	2016 $50,000	2017 $50,000
Total Funding:	$200,000		
Project ID:	BA14006		
Chief Investigators:	H. K. Liu, Z. P. Guo, J. Z. Wang, J. H. Kim, K. Konstantinov, S. L. Chou		
Project Summary:	The global market for energy storage, including lithium ion batteries (LIBs) for electric vehicles (EVs), will experience unprecedented growth in the next decade. The challenges of EV LIBs are related to the materials used in the LIBs. This project aims to study high energy anode materials with reduced cost and improved safety to meet the requirements for the next generation of LIBs and make them more suitable for EVs.		



Prof. Wei Huang (Nanjing Tech University) accepting his Honorary Fellowship from the University of Wollongong Vice-Chancellor Prof. Paul Wellings

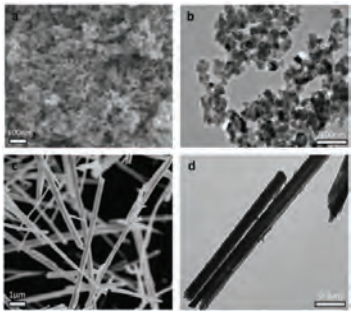
Selected Abstracts

Fish-scale bio-inspired multifunctional ZnO nanostructures



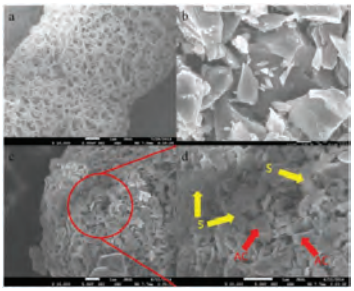
Scales provide optical disguise, low water drag and mechanical protection to fish, enabling them to survive catastrophic environmental disasters, predators and microorganisms. The unique structures and stacking sequences of fish scales inspired the fabrication of artificial nanostructures with salient optical, interfacial and mechanical properties. Herein, we describe fish-scale bio-inspired multifunctional ZnO nanostructures that have similar morphology and structure to the cycloid scales of the Asian Arowana. These nanostructured coatings feature tunable light refraction and reflection, modulated surface wettability and damage-tolerant mechanical properties. The salient properties of these multifunctional nanostructures are promising for applications in (i) optical coatings, sensing or lens arrays for use in reflective displays, packing, advertising and solar energy harvesting; (ii) self-cleaning surfaces, including anti-smudge, anti-fouling and anti-fogging, and self-sterilizing surfaces; and (iii) mechanical/chemical barrier coatings. This study provides a low-cost and large-scale production method for the facile fabrication of these bio-inspired nanostructures and provides new insights for the development of novel functional materials for use in 'smart' structures and applications. (Z. Q. Sun et al., ***NPG Asia Materials* 7**, e232 (2015))

Boosting the efficiency of quantum dot sensitized solar cells up to 7.11% through simultaneous engineering of photocathode and photoanode



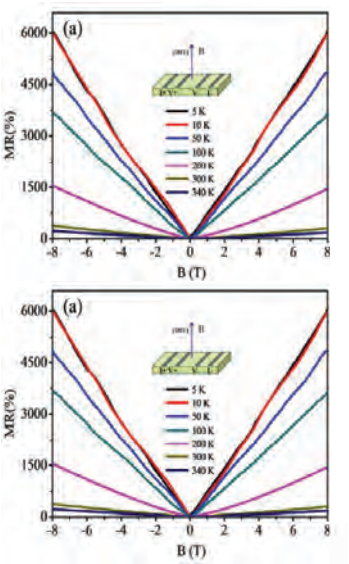
We demonstrate a new strategy of boosting the efficiency of quantum dot sensitized solar cells (QDSSCs) by engineering the photocathode and photoanode simultaneously. Nanostructured photocathodes based on non-stoichiometric $Cu_{2-x}Se$ electrocatalysts were developed via a simple and scalable approach for CdS/CdSe QDs co-sensitized solar cells. Compared to Cu_2S CE, remarkably improved photovoltaic performance was achieved for QDSSCs with $Cu_{2-x}Se$ CEs. The superior catalytic activity and electrical conductivity of $Cu_{2-x}Se$ CEs were verified by the electrochemical impedance spectra and Tafel-polarization measurements. To maximize the efficiency enhancement, the photoanodes were optimized by introducing a pillared porous titania composite as the scattering layers for further light harvesting and charge transfer improvement concurrently. The combination of effective $Cu_{2-x}Se$ electrocatalysts and pillared titania scattering layers contributed to one of the best reported efficiencies of 7.11% for CdS/CdSe QDs co-sensitized solar cells. (Y. Bai et al., ***Nano Energy* 13**, 609 (2015))

A systematic approach to high and stable discharge capacity for scaling up the lithium-sulfur battery



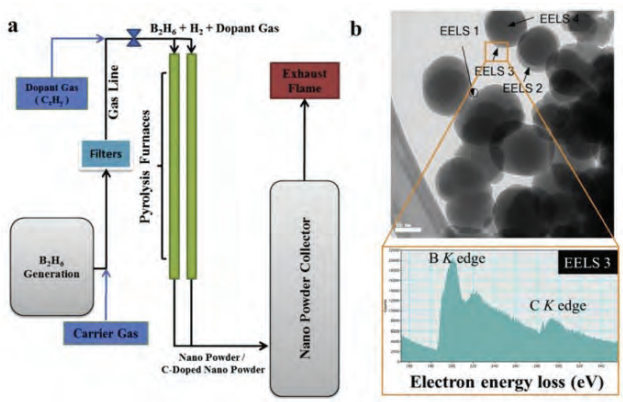
A systematic approach to improving the performance of the LieS battery is presented, based on applying high energy ball milling to create a porous sulfurecarbon composite, insertion of a free-standing layer, and adoption of a new charging method. Surface area analysis and field emission scanning electron microscope imaging show that the ball-milled sulfur powder has a porous structure and very high specific surface area. A vacuum-filtrated single-walled carbon nanotube free-standing layer is inserted in between the sulfur cathode and the separator. It is believed that high-surface-area porous sulfur will help to increase the conductivity of the elemental sulfur due to better adhesion between the conducting carbon and the sulfur, while the free-standing layer will sequester longer chain polysulfides, which are responsible for the well-known shuttling phenomenon. By the combination of these methods, we have achieved excellent capacity and cycle life. Finally, a new charging method which will largely prevent the formation of longer chain polysulfides is also applied to increase the capacity retention. It is believed that with the combination of ball milling, the free-standing layer, and the new charging method, it is possible to commercialize the LieS battery with better capacity and cycle life. (M. R. Kaiser et al., ***Journal of Power Sources* 279**, 231 (2015))

Semimetal-semiconductor transition and giant linear magnetoresistances in three-dimensional Dirac semimetal $Bi_{0.96}Sb_{0.04}$ single crystals



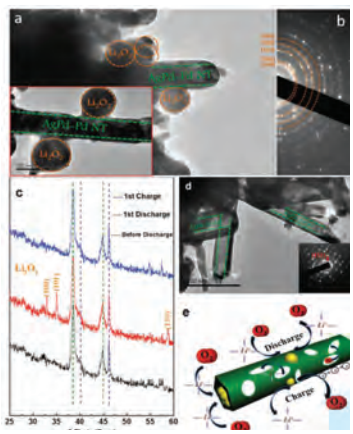
Three-dimensional (3D) Dirac semimetals are new quantum materials and can be viewed as 3D analogues of graphene. Many fascinating electronic properties have been proposed and realized in 3D Dirac semimetals, which demonstrate their potential applications in next generation quantum devices. Bismuth-antimony $Bi_{1-x}Sb_x$ can be tuned from a topological insulator to a band insulator through a quantum critical point at x≈4%, where 3D Dirac fermions appear. Here, we report on a magnetotransport study of $Bi_{1-x}Sb_x$ at such a quantum critical point. An unusual magnetic-field induced semimetal-semiconductor phase transition was observed in the $Bi_{0.96}Sb_{0.04}$ single crystals. In a magnetic field of 8 T, $Bi_{0.96}Sb_{0.04}$ single crystals show giant magnetoresistances of up to 6000% at low-temperature, 5K, and 300% at room-temperature, 300 K. The observed magnetoresistances keep linear down to approximate zero-field when the temperature is below 200 K. Our experimental results are not only interesting for the fundamental physics of 3D Dirac semimetals but also for potential applications of 3D Dirac semimetals in magnetoelectronic devices. (Z. J. Yue et al., ***Applied Physics Letters*** **107**, 112101 (2015))

Superior critical current density obtained in MgB_2 bulks through low-cost carbon-encapsulated boron powder



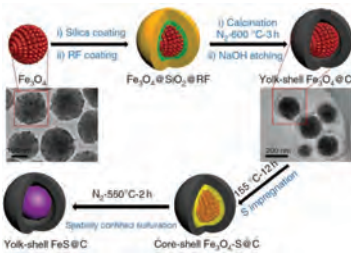
The unavailability of high quality precursor is encouraging researchers to seek effective ways to fabricate magnesium diboride (MgB_2) wire. Herein, cost-effective amorphous boron powder produced through a diborane (B_2H_6) gas process is investigated for the possibility of further industrial application. A thin carbon layer to encapsulate the boron particles is simultaneously deposited by pyrolysis of hydrocarbon. We found that the carbon-encapsulated amorphous boron has a high upper critical field due to impurity scattering, and thereby, enhanced high-field critical current density. (S. Barua et al., ***Scripta Materialia*** **104**, 37 (2015))

Porous AgPd–Pd composite nanotubes as highly efficient electrocatalysts for lithium–oxygen batteries



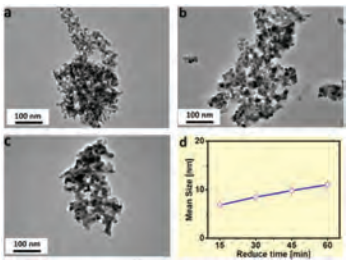
On page 6862, S.-L. Chou and co-workers present an AgPd–Pd porous nanotube with porous channels that facilitates rapid O_2 and electrolyte diffusion and forms a 3D continuous conductive air electrode network in lithium–oxygen batteries. It acts as an efficient bifunctional catalyst for the oxygen reduction reaction and oxygen evolution reaction, promoting Li_2O_2 to nucleate and decompose on the surface and inside of the nanotubes. (W. B. Luo et al., ***Advanced Materials*** **27**, 6862 (2015))

Uniform yolk-shell iron sulfide–carbon nanospheres for superior sodium–iron sulfide batteries



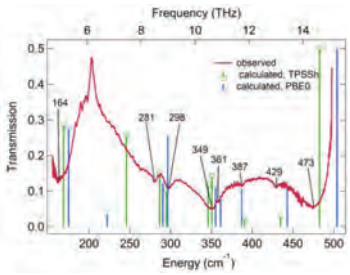
Sodium–metal sulfide battery holds great promise for sustainable and cost-effective applications. Nevertheless, achieving high capacity and cycling stability remains a great challenge. Here, uniform yolk-shell iron sulfide–carbon nanospheres have been synthesized as cathode materials for the emerging sodium sulfide battery to achieve remarkable capacity of ~545 mAh g^{-1} over 100 cycles at 0.2 C (100mAg^{-1}), delivering ultrahigh energy density of ~438Whkg^{-1}. The proven conversion reaction between sodium and iron sulfide results in high capacity but severe volume changes. Nanostructural design, including of nanosized iron sulfide yolks (~170 nm) with porous carbon shells (~30 nm) and extra void space (~20 nm) in between, has been used to achieve excellent cycling performance without sacrificing capacity. This sustainable sodium–iron sulfide battery is a promising candidate for stationary energy storage. Furthermore, this spatially confined sulfuration strategy offers a general method for other yolk-shell metal sulfide–carbon composites. (Y. X. Wang et al., ***Nature Communications*** **6**, 8689 (2015))

Robust scalable synthesis of surfactant-free thermoelectric metal chalcogenide nanostructures



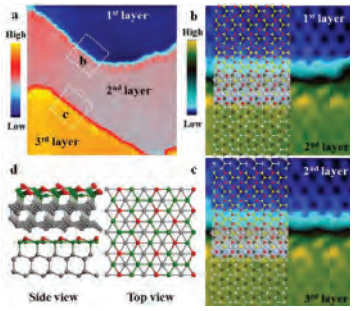
A robust low-cost ambient aqueous method for the scalable synthesis of surfactant-free nanostructured metal chalcogenides (M_aX_b, M=Cu, Ag, Sn, Pb, and Bi; X=S, Se, and Te; a=1 or 2; and b=1 or 3) is developed in this work. The effects of reaction parameters, such as precursor concentration, ratio of precursors, and amount of reducing agent, on the composition, size, and shape of the resultant nano structures have been comprehensively investigated. This environmentally friendly approach is capable of producing metal chalcogenide nano structures in a one pot reaction on a large scale, which were investigated for their thermoelectric properties towards conversion of waste heat into electricity. The results demonstrate that the thermoelectric properties of these metal chalcogenide nanostructures are strongly dependent on the types of metal chalcogenides, and their figure of merits are comparable with previously reported figures for their bulk or nanostructured counterparts. (C. Han et al., ***Nano Energy*** **15**, 193 (2015))

Terahertz spectroscopy of 2,4-dinitrotoluene over a wide temperature range (7–245 K)



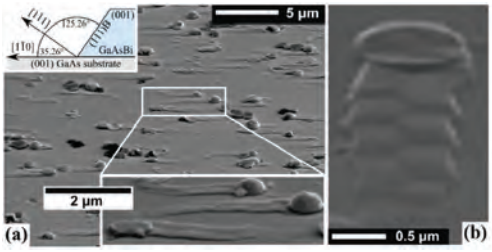
Previous THz spectroscopy of the TNT explosive precursor, 2,4-dinitrotoluene (DNT), has been restricted to room temperature (apart from one set of data at 11 K). Here, for the first time, we investigate the spectrum as the temperature is systematically varied, from 7 to 245 K. Many new features appear in the spectrum on cooling below room temperature. As well as the five absorption lines observed previously, we observe five additional lines. In addition, a new room-temperature line at 8.52 THz (281 cm^{-1}) is observed. Six of the lines red-shift with temperature and four of them blue-shift. The blue shift is explained by interplay between intramolecular and intermolecular hydrogen bonds. The variation in line width and line intensity with temperature is not systematic, although a conspicuous decrease in line intensity with temperature is observed in all cases. Modeling with hybrid PBE0 and TPSSh functionals helps identify absorption modes. (L. M. Lepodise et al., *The* ***Journal of Physical Chemistry A*** **119**, 263 (2015))

Delocalized surface state in epitaxial Si(111) film with spontaneous √3 × √3 superstructure



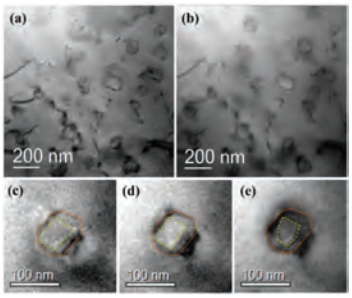
The "multilayer silicene" films were grown on Ag(111), with increasing thickness above 30 monolayers (ML). Scanning tunneling microscopy (STM) observations suggest that the "multilayer silicene" is indeed a bulk-like Si(111) film with a (√3 × √3)R30° honeycomb superstructure on surface. The possibility for formation of Si(111)(√3 × √3)R30°-Ag reconstruction on the surface can be distinctively ruled out by peeling off the surface layer with the STM tip. On this surface, delocalized surface state as well as linear energy-momentum dispersion was observed from quasiparticle interference patterns. Our results indicate that a bulklike silicon film with diamondlike structure can also host delocalized surface state, which is even more attractive for potential applications, such as new generation of nanodevices based on Si. (J. Chen et al., ***Scientific Reports*** **5**, 13590 (2015))

Mechanism of periodic height variations along self-aligned VLS-grown planar nanostructures



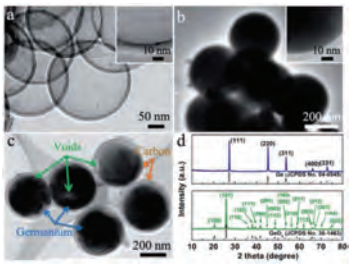
In this study we report in-plane nanotracks produced by molecular-beam-epitaxy (MBE) exhibiting lateral self-assembly and unusual periodic and out-of-phase height variations across their growth axes. The nanotracks are synthesized using bismuth segregation on the GaAsBi epitaxial surface, which results in metallic liquid droplets capable of catalyzing GaAsBi nanotrack growth via the vapor–liquid–solid (VLS) mechanism. A detailed examination of the nanotrack morphologies is carried out employing a combination of scanning electron and atomic force microscopy and, based on the findings, a geometric model of nanotrack growth during MBE is developed. Our results indicate diffusion and shadowing effects play significant roles in defining the interesting nanotrack shape. The unique periodicity of our lateral nanotracks originates from a rotating nucleation "hot spot" at the edge of the liquid–solid interface, a feature caused by the relative periodic circling of the non-normal ion beam flux incident on the sample surface, inside the MBE chamber. We point out that such a concept is divergent from current models of crawling mode growth kinetics and conclude that these effects may be utilized in the design and assembly of planar nanostructures with controlled non-monotonous structure. (J. A. Steele et al., ***Nanoscale*** **7**, 20442 (2015))

Heterogeneous distribution of sodium for high thermoelectric performance of p-type multiphase lead-chalcogenides



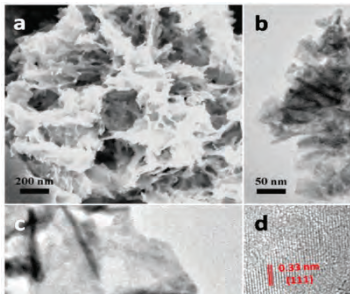
Despite the effectiveness of sodium as a p-type dopant for lead chalcogenides, its solubility is shown to be very limited in these hosts. Here, a high thermoelectric effi ciency of ≈2 over a wide temperature range is reported in multiphase quaternary (PbTe) 0.65 (PbS) 0.25 (PbSe) 0.1 compounds that are doped with sodium at concentrations greater than the solubility limits of the matrix. Although these compounds present room temperature thermoelectric effi ciencies similar to sodium doped PbTe, a dramatically enhanced Hall carrier mobility at temperatures above 600 K for heavily doped compounds results in signifi cantly enhanced thermoelectric effi ciencies at elevated temperatures. This is achieved through the composition modulation doping mechanism resulting from heterogeneous distribution of the sodium dopant between precipitates and the matrix at elevated temperatures. These results can lead to further advances in designing high performance multiphase thermo electric materials with intrinsically heterogeneous dopant distributions. (S. Aminorroaya-Yamini et al., ***Advanced Energy Materials*** **5**, 1501047 (2015))

Hollow carbon spheres with encapsulated germanium as an anode material for lithium ion batteries



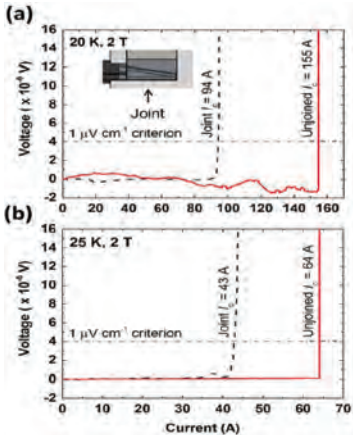
A novel composite consisting of hollow carbon spheres with encapsulated germanium (Ge@HCS) was synthesized by introducing a germanium precursor into the porous-structured hollow carbon spheres. The carbon spheres not only function as a scaffold to hold the germanium and thus maintain the structural integrity of the composite, but also increase the electrical conductivity. The voids and vacancies that are formed after the reduction of germaniumdioxide to germanium provide free space for accommodating the volume changes during discharging–charging processes, thus preventing pulverization. The obtained Ge@HCS composite exhibits excellent lithium storage performance, as revealed by electrochemical evaluation. (D. Li et al., ***Journal of Materials Chemistry*** *A* **3**, 978 (2015))

Ambient facile synthesis of gram-scale copper selenide nanostructures from commercial copper and selenium powder



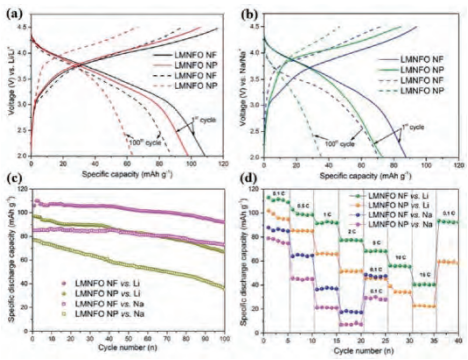
Grams of copper selenides ($Cu_{2-x}Se$) were prepared from commercial copper and selenium powders in the presence of thiol ligands by a one-pot reaction at room temperature. The resultant copper selenides are a mixture of nanoparticles and their assembled nanosheets, and the thickness of nanosheets assembled is strongly dependent on the ratio of thiol ligand to selenium powder. The resultant $Cu_{2-x}Se$ nanostructures were treated with hydrazine solution to remove the surface ligands and then explored as a potential thermoelectric candidate in comparison with commercial copper selenide powders. The research provides a novel ambient approach for preparation of $Cu_{2-x}Se$ nanocrystallines on a large scale for various applications. (X. Q. Chen et al., ***ACS Applied Materials & Interfaces*** **7**, 13295 (2015))

MgB_2 superconducting joints for persistent current operation



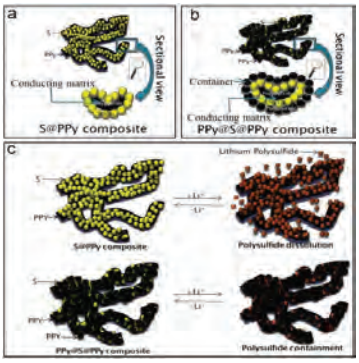
High-performance superconducting joints are essential for realizing persistent-mode magnets. Herein, we propose a concept and fabrication of such superconducting joints, which yielded reliable performance in the operating temperature range of 4.2–25 K. MgB_2–MgB_2 joints in magnets are known to result in deterioration of localized electrical, thermal, and mechanical properties. To overcome these problems, the ends of the two wires are inserted into a pellet press, which is then filled with a mixture of unreacted magnesium and boron powders, followed by heat treatment. The critical current capacity and joint resistance were precisely evaluated by the standard four-probe method in open-circuit and by field-decay measurements in a closed-loop, respectively. These joints demonstrated up to 66% of the current-carrying capacity of unjoined wire at 20 K, 2 T and joint resistance of 1.4×10^{-12} Ω at 4.2 K in self-field. (D. Patel et al., ***Superconductor Science & Technology*** **28**, 065017 (2015))

One-dimensional nanostructured design of $Li_{1+x}(Mn_{1/3}Ni_{1/3}Fe_{1/3})O_2$ as a dual cathode for lithium-ion and sodium-ion batteries



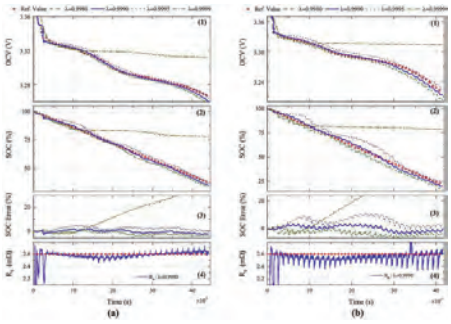
Potency of the cathode material is an important feature for upgrading lithium-ion/sodium-ion battery technology for next-generation applications such as in electrical grids and advanced electric vehicles. Various limitations related to electrochemical and socio-economic issues of these batteries are current research challenges. Amongst the various possible solutions to address such issues, developing nanostructured cathode materials, such as one-dimensional nanostructures, by versatile and easily scaled-up processes could be one of the options. Consequently, in the present study, $Li_{1+x}(Mn_{1/3}Ni_{1/3}Fe_{1/3})O_2$ onedimensional nanofibers have been fabricated via a simple and low-cost electrospinning technique and used as a cathode material in lithium-ion batteries, which showed an improved initial reversible capacity (~109 mA h g^{-1}) and cyclic stability at the 0.1 C rate when compared to the performance of $Li_{1+x}(Mn_{1/3}Ni_{1/3}Fe_{1/3})O_2$ nanoparticles. On the other hand, the feasibility of this low-cost and eco-friendly material was also tested in sodium-ion batteries, and the same trend is observed. The enhanced electrochemical and structural features in both systems could be ascribed to the exceptional features of one-dimensional nanofibers such as efficient electron transport, facile strain relaxation, and short Li^+/Na^+ diffusion pathways. (S. Kalluri et al., ***Journal of Materials Chemistry*** *A* **3**, 250 (2015))

Split-half-tubular polypyrrole@sulfur@polypyrrole composite with a novel three-layer-3D structure as cathode for lithium/sulfur batteries



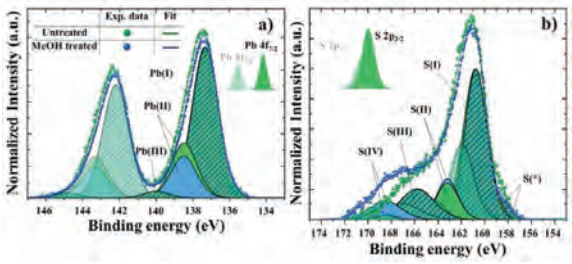
Polypyrrole@Sulfur@Polypyrrole composite with a novel three-layer-3D-structure, which consists of an external polypyrrole coating layer, an intermediate sulfur filling layer, and an internal polypyrrole split-half-tube conducting matrix layer, has been synthesized by the oxidative chemical polymerization method and chemical precipitation method in this article. Due to this unique three-layer-structure, the discharge specific capacity of Polypyrrole@Sulfur@Polypyrrole composite cathode retained at 554mAhg^{-1} after 50 cycles, which represents 68.8% retention of the initial discharge specific capacity. In comparison, the Sulfur@Polypyrrolecomposite cathode, with the same components as Polypyrrole@Sulfur@Polypyrrole composite, but without the three layer structure, has the discharge specific capacity of 370 mAhg^{-1} after 50 cycles, which is 32.3% retention of the initial discharge specific capacity. Therefore, it can be concluded that the unique three-layer-structure plays an essential role in improving the performance of the Lithium/Sulfur batteries. Moreover, the effects of $LiNO_3$ additive in the electrolyte on coulombic efficiency are discussed to further confirm the containment function of the external layer of polypyrrole in the Polypyrrole@Sulfur@Polypyrrole composite, which is the evidence that the external layer of polypyrrole can effectively confine the dissolved polysulfides. (X. Liang et al., ***Nano Energy*** **11**, 587 (2015))

Online state of charge and model parameters estimation of the $LiFePO_4$ battery in electric vehicles using multiple adaptive forgetting factors recursive least-squares



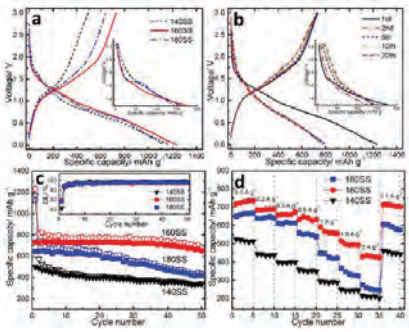
This paper deals with the contradiction between simplicity and accuracy of the $LiFePO_4$ battery states estimation in the electric vehicles (EVs) battery management system (BMS). State of charge (SOC) and state of health (SOH) are normally obtained from estimating the open circuit voltage (OCV) and the internal resistance of the equivalent electrical circuit model of the battery, respectively. The difficulties of the parameters estimation arise from their complicated variations and different dynamics which require sophisticated algorithms to simultaneously estimate multiple parameters. This, however, demands heavy computation resources. In this paper, we propose a novel technique which employs a simplified model and multiple adaptive forgetting factors recursive least-squares (MAFF-RLS) estimation to provide capability to accurately capture the real-time variations and the different dynamics of the parameters whilst the simplicity in computation is still retained. The validity of the proposed method is verified through two standard driving cycles, namely Urban Dynamometer Driving Schedule and the New European Driving Cycle. The proposed method yields experimental results that not only estimated the SOC with an absolute error of less than 2.8% but also characterized the battery model parameters accurately. (V. H. Duong et al., ***Journal of Power Sources*** **296**, 215 (2015))

The effect of surface passivation on the structure of sulphur-rich PbS colloidal quantum dots for photovoltaic application



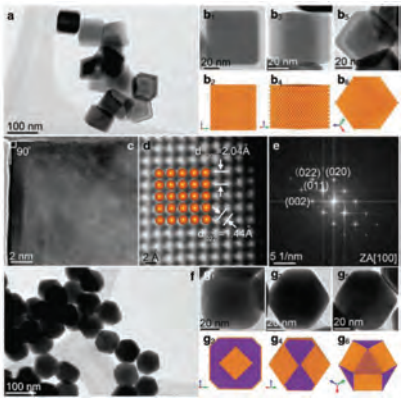
The use of PbS colloidal quantum dots in photovoltaic devices is very promising because of their simple and low cost production processes and their unique properties, such as bandgap tunability and potential multiple exciton generation. Here we report the synthesis of PbS nanocrystals used for application in solar cells. The sulphur-rich nature of their surface appears to be caused by the exposure to ambient conditions. The use of methanol as medium during the ligand exchange process has a crucial role in the removal of native oleate ligands. Without proper ligand exchange, the unpassivated surface is subject to ambient hydroxylation leading to the depletion of Pb atoms and the formation of a polysulfide phase. Devices assembled with this material showed good performance with an efficiency of 3.2%. (V. Malgras et al., ***Nanoscale*** **7**, 5706 (2015))

Two-dimensional tin disulfide nanosheets for enhanced sodium storage



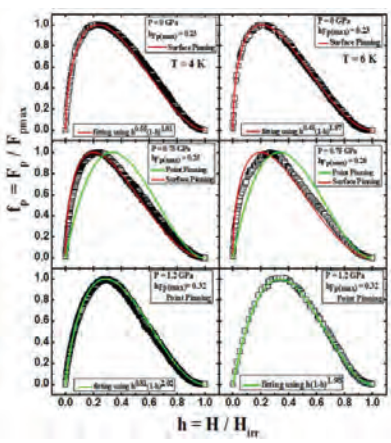
Sodium-ion batteries (SIBs) are considered as complementary alternatives to lithium-ion batteries for grid energy storage due to the abundance of sodium. However, low capacity, poor rate capability, and cycling stability of existing anodes significantly hinder the practical applications of SIBs. Herein, ultrathin two-dimensional SnS_2 nanosheets (3-4 nm in thickness) are synthesized via a facile refluxing process toward enhanced sodium storage. The SnS_2 nanosheets exhibit a high apparent diffusion coefficient of Naþ and fast sodiation/desodiation reaction kinetics. In half-cells, the nanosheets deliver a high reversible capacity of 733 mAhg^{-1} at 0.1 A g^{-1}, which still remains up to 435 mAh g^{-1} at 2 A g^{-1}. The cell has a high capacity retention of 647 mAh g^{-1} during the 50th cycle at 0.1 A g^{-1}, which is by far the best for SnS_2, suggesting that nanosheet morphology is beneficial to improve cycling stability in addition to rate capability. The SnS_2 nanosheets also show encouraging performance in a full cell with a $Na_3V_2(PO_4)_3$ cathode. In addition, the sodium storage mechanism is investigated by ex situ XRD coupled with high-resolution TEM. The high specific capacity, good rate capability, and cycling durability suggest that SnS_2 nanosheets have great potential working as anodes for high-performance SIBs (W. P. Sun et al., ***ACS Nano* 9**, 11371 (2015))

Gold nanocrystals with variable index facets as highly effective cathode catalysts for lithium–oxygen batteries



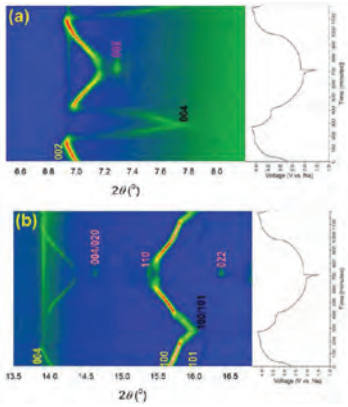
Cathode catalysts are the key factor in improving the electrochemical performance of lithium–oxygen (Li–O_2) batteries via their promotion of the oxygen reduction and oxygen evolution reactions (ORR and OER). Generally, the catalytic performance of nanocrystals (NCs) toward ORR and OER depends on both composition and shape. Herein, we report the synthesis of polyhedral Au NCs enclosed by a variety of index facets: cubic gold (Au) NCs enclosed by {100} facets; truncated octahedral Au NCs enclosed by {100} and {110} facets; and trisoctahedral (TOH) Au NCs enclosed by 24 high-index {441} facets, as effective cathode catalysts for Li–O_2 batteries. All Au NCs can significantly reduce the charge potential and have high reversible capacities. In particular, TOH Au NC catalysts demonstrated the lowest charge-discharge overpotential and the highest capacity of ~ 20298 mAh g^{-1}. The correlation between the different Au NC crystal planes and their electrochemical catalytic performances was revealed: high-index facets exhibit much higher catalytic activity than the low-index planes, as the high-index planes have a high surface energy because of their large density of atomic steps, ledges and kinks, which can provide a high density of reactive sites for catalytic reactions. (D. W. Su et al., ***NPG Asia Materials* 7**, e155 (2015))

Hydrostatic pressure: A very effective approach to significantly enhance critical current density in granular iron pnictide superconductors



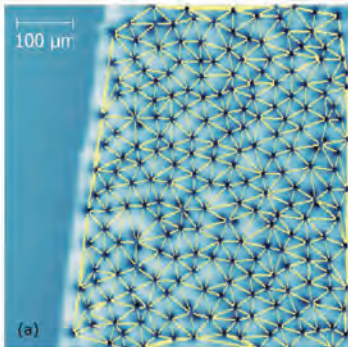
Pressure is well known to significantly raise the superconducting transition temperature, Tc, in both iron pnictides and cuprate based superconductors. Little work has been done, however, on how pressure can affect the flux pinning and critical current density in the Fe-based superconductors. Here, we propose to use hydrostatic pressure to significantly enhance flux pinning and Tc in polycrystalline pnictide bulks. We have chosen $Sr_4V_2O_6Fe_2As_2$ polycrystalline samples as a case study.Wedemonstrate that the hydrostatic pressure up to 1.2 GPa can not only significantly increase Tc from 15 K (underdoped) to 22 K, but also significantly enhance the irreversibility field,H_{irr}, by a factor of 4 at 7 K, as well as the critical current density, J_c, by up to 30 times at both low and high fields. It was found that pressure can induce more point defects, which are mainly responsible for the J_c enhancement. Our findings provide an effective method to significantly enhance T_c, J_c, H_{irr}, and the upper critical field, H_{c2}, for other families of Fe-based superconductors in the forms of wires/tapes, films, and single crystal and polycrystalline bulks. (B. Shabbir et al., ***Scientific Reports* 7**, 794 (2014))

Interplay between electrochemistry and phase evolution of the P2-type $Na_x(Fe_{1/2}Mn_{1/2})O_2$ cathode for use in sodium-ion batteries



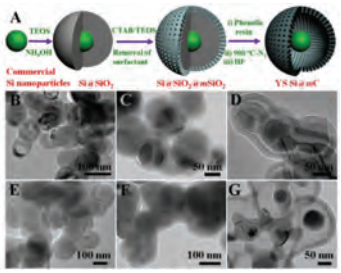
Sodium-ion batteries are the next-generation in battery technology; however, their commercial development is hampered by electrode performance. The P2-type Na2/3(Fe1/2Mn1/2)O2 with a hexagonal structure and P63/mmc space group is considered a candidate sodium-ion battery cathode material due to its high capacity (~190 mAh·g-1) and energy density (~520 mWh·g-1), which are comparable to those of the commercial LiFePO4 and LiMn2O4 lithium-ion battery cathodes, with previously unexplained poor cycling performance being the major barrier to its commercial application. We use operando synchrotron X-ray powder diffraction to understand the origins of the capacity fade of the Na2/3(Fe1/2Mn1/2)O2 material during cycling over the relatively wide 1.5-4.2 V (vs Na) window. We found a complex phase-evolution, involving transitions from P63/mmc (P2-type at the open-circuit voltage) to P63 (OP4-type when fully charged) to P63/mmc (P2-type at 3.4-2.0 V) to Cmcm (P2-type at 2.0-1.5 V) symmetry structures during the desodiation and sodiation of the Na2/3(Fe1/2Mn1/2)O2 cathode. The associated large cellvolume changes with the multiple two-phase reactions are likely to be responsible for the poor cycling performance, clearly suggesting a 2.0-4.0 V window of operation as a strategy to improve cycling performance. We demonstrated here that the P2-type Na2/3(Fe1/2Mn1/2)O2 cathode is able to deliver ~25% better cycling performance with the strategic operation window. This significant improvement in cycling performance implies that by characterizing the phase evolution and reaction mechanisms during battery function we are able to propose these modifications to the conditions of battery use that improve performance, highlighting the importance of the interplay between structure and electrochemistry. (W. K. Pang et al., Chemistry of Materials 27, 3150 (2015))

Analysis of low-field isotropic vortex glass containing vortex groups in $YBa_2Cu_3O_{7-x}$ thin films visualized by scanning SQUID microscopy



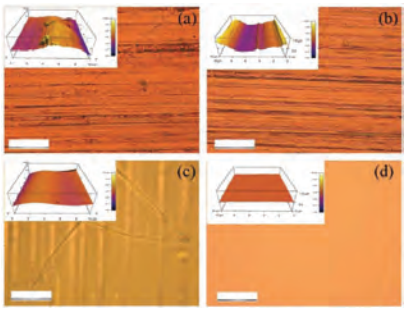
The glass-like vortex distribution in pulsed laser deposited $YBa_2Cu_3O_{7-x}$ thin films is observed by scanning superconducting quantum interference device microscopy and analysed for ordering after cooling in magnetic fields significantly smaller than the Earth's field. Autocorrelation calculations on this distribution show a weak short-range positional order, while Delaunay triangulation shows a near-complete lack of orientational order. The distribution of these vortices is finally characterised as an isotropic vortex glass. Abnormally closely spaced groups of vortices, which are statistically unlikely to occur, are observed above a threshold magnetic field. The origin of these groups is discussed, but will require further investigation. (F. S. Wells et al., ***Scientific Reports*** **5**, 8677 (2015))

Yolk-shell silicon-mesoporous carbon anode with compact solid electrolyte interphase film for superior lithium-ion batteries



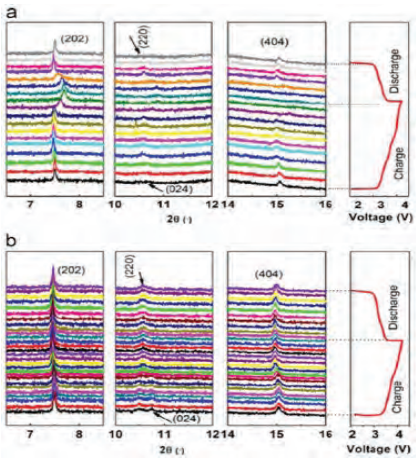
Silicon as an electrode suffers from short cycling life, as well as unsatisfactory rate-capability caused by the large volume expansion (~400%) and the consequent structural degradation during lithiation/ delithiation processes. Here, we have engineered unique void-containing mesoporous carbon- encapsulated commercial silicon nanoparticles (NPs) in yolk-shell structures. In this design, the silicon NPs yolk are wrapped into open and accessible mesoporous carbon shells, the void space between yolk and shell provides enough room for Si expansion, meanwhile, the porosity of carbon shell enables fast transport of Li^+ ions between electrolyte and silicon. Our ex-situ characterization clearly reveals for the first time that a favorable homogeneous and compact solid electrolyte interphase (SEI) film is formed along the mesoporous carbon shells. As a result, such yolk-shell Si@mesoporous-carbon nanoparticles with a large void exhibits long cycling stability (78.6% capacity retention as long as 400 cycles), and superior rate-capability (62.3% capacity retention at a very high current density of 8.4 Ag^{-1}). (J. P. Yang et al., ***Nano Energy*** **18**, 133 (2015))

Synthesis of large and few atomic layers of hexagonal boron nitride on melted copper



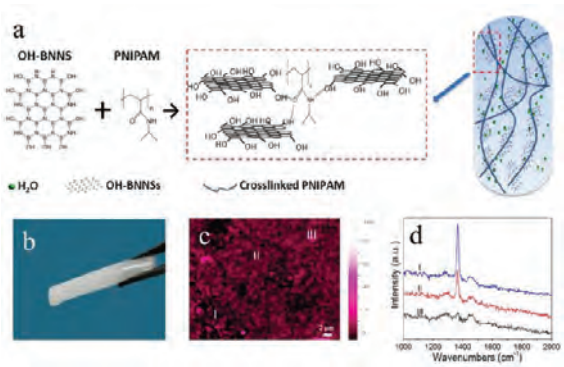
Hexagonal boron nitride nanosheets (h-BNNS) have been proposed as an ideal substrate for graphene-based electronic devices, but the synthesis of large and homogeneous h-BNNS is still challenging. In this contribution, we report a facile synthesis of few-layerh-BNNS on melted copper via an atmospheric pressure chemical vapor deposition process. Comparative studies confirm the advantage of using melted copper over solid copper as a catalyst substrate. The former leads to the formation of single crystalline h-BNNS that is several microns in size and mostly in mono- and bi-layer forms, in contrast to the polycrystalline and mixed multiple layers (1–10) yielded by the latter. This difference is likely to be due to the significantly reduced and uniformly distributed nucleation sites on the smooth melted surface, in contrast to the large amounts of unevenly distributed nucleation sites that are associated with grain boundaries and other defects on the solid surface. This synthesis is expected to contribute to the development of large-scale manufacturing of h-BNNS/graphene-based electronics. (M. H. Khan et al., ***Scientific Reports*** **5**, 7743 (2015))

Multifunctional conducting polymer coated $Na_{1+x}MnFe(CN)_6$ cathode for sodium-ion batteries with superior performance via a facile and one-step chemistry approach



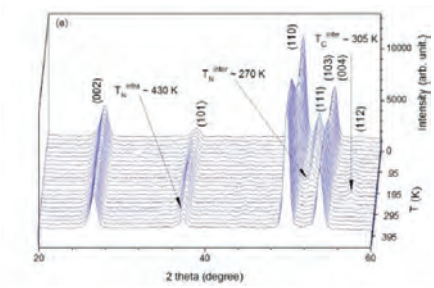
A facile, one-step, soft chemistry approach is developed to synthesize doped polypyrrole coated $Na_{1+x}MnFe(CN)_6$ composite as a cathode material (NMHFC@PPy) for SIBs. PPy plays multiple important roles in the composite. First, PPy serves as a conductive coating layer which can increase the electronic conductivity of NMHFC to improve the rate capability. Second, PPy can act as a protective layer to reduce the dissolution of Mn in the electrolyte to improve the cycling performance. Finally, the PPy doped with can act as active materials to increase the capacity of the composite. NMHFC@PPy shows high energy density (428 $Whkg^{-1}$), enhanced cycling performance (67% capacity retention after 200 cycles), and excellent rate capacity (46% capacity for 40C rate). (W. J. Li et al., ***Nano Energy*** **13**, 200 (2015))

Edge-hydroxylated boron nitride nanosheets as an effective additive to improve the thermal response of hydrogels



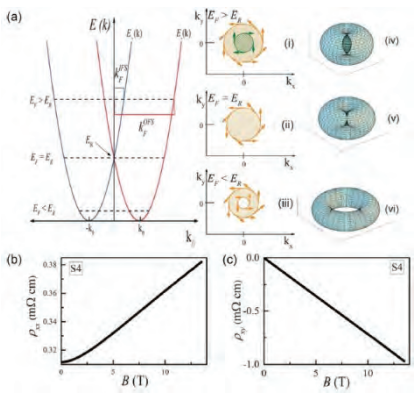
Upon flowing hot steam over hexagonal boron nitride (h-BN) bulk powder, efficient exfoliation and hydroxylation of BN occur simultaneously. Through effective hydrogen bonding with water and Nisopropylacrylamide, edge-hydroxylated BN nanosheets dramatically improve the dimensional change and dye release of this temperature-sensitive hydrogel and thereby enhance its efficacy in bionic, soft robotic, and drug-delivery applications. (F. Xiao et al., ***Advanced Materials*** **27**, 7196 (2015))

Tuneable magnetic phase transitions in layered $CeMn_2Ge_{2-x}Si_x$ compounds



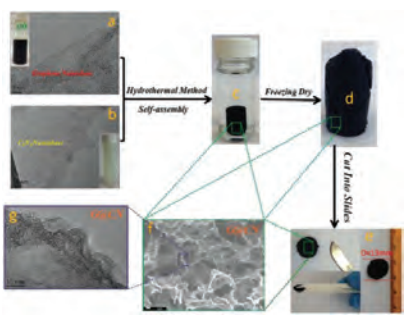
The structural and magnetic properties of seven $CeMn_2Ge_{2-x}Si_x$ compounds with x = 0.0–2.0 have been investigated in detail. Substitution of Ge with Si leads to a monotonic decrease of both a and c along with concomitant contraction of the unit cell volume and significant modifications of the magnetic states - a crossover from ferromagnetism at room temperature for Ge-rich compounds to antiferromagnetism for Si-rich compounds. The magnetic phase diagram has been constructed over the full range of $CeMn_2Ge_{2-x}Si_x$ compositions and co-existence of ferromagnetism and antiferromagnetism has been observed in $CeMn_2Ge_{1.2}Si_{0.8}$, $CeMn_2Ge_{1.0}Si_{1.0}$ and $CeMn_2Ge_{0.8}Si_{1.2}$ with novel insight provided by high resolution neutron and X-ray synchrotron radiation studies. $CeMn_2Ge_{2-x}Si_x$ compounds (x = 0, 0.4 and 0.8) exhibit moderate isothermal magnetic entropy accompanied with a second-order phase transition around room temperature. Analysis of critical behaviour in the vicinity of TC inter for $CeMn_2Ge_2$ compound indicates behaviour consistent with three-dimensional Heisenberg model predictions. (M. F. Md Din et al., ***Scientific Reports*** **5**, 11288 (2015))

Observation of topological transition of Fermi surface from a spindle torus to a torus in bulk Rashba spin-split BiTeCl



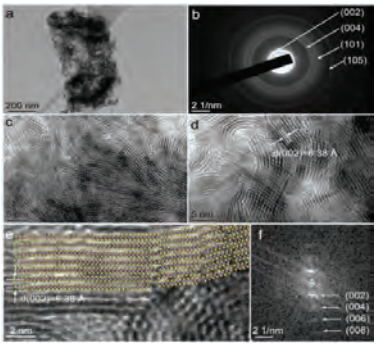
The recently observed large Rashba-type spin splitting in the BiTe*X* (*X* = I, Br, Cl) bulk states enables observation of the transition in Fermi surface topology from spindle torus to torus with varying the carrier density and offers an ideal platform for achieving practical spintronic applications and realizing nontrivial phenomena such as topological superconductivity and Majorana fermions. Here we use Shubnikov–de Haas oscillations to investigate the electronic structure of the bulk conduction band of BiTeCl single crystals with different carrier densities.We observe the topological transition of the Fermi surface (FS) from a spindle torus to a torus. The Landau-level fan diagram reveals the expected nontrivial ϖ Berry phase for both the inner and outer FSs. Angle-dependent oscillation measurements reveal three-dimensional FS topology when the Fermi level lies in the vicinity of the Dirac point. All the observations are consistent with large Rashba spin-orbit splitting in the bulk conduction band. (F. X. Xiang et al., ***Physical Review B*** **92**, 035123 (2015))

A metal-free, free-standing, macroporous graphene@g-C_3N_4 composite air electrode for high-energy lithium oxygen batteries



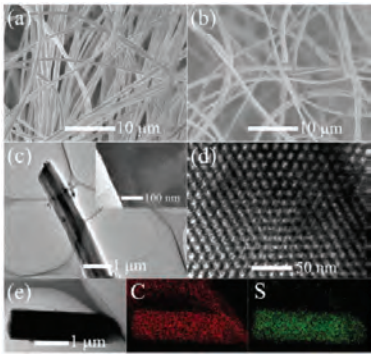
The nonaqueous lithium oxygen battery is a promising candidate as a nextgeneration energy storage system because of its potentially high energy density (up to 2–3 kW kg^{-1}), exceeding that of any other existing energy storage system for storing sustainable and clean energy to reduce greenhouse gas emissions and the consumption of nonrenewable fossil fuels. To achieve high energy density, long cycling stability, and low cost, the air electrode structure and the electrocatalysts play important roles. Here, a metal-free, free-standing macroporous graphene@graphitic carbon nitride (g-C_3N_4) composite air cathode is first reported, in which the g-C_3N_4 nanosheets can act as efficient electrocatalysts, and the macroporous graphene nanosheets can provide space for Li_2O_2 to deposit and also promote the electron transfer. The electrochemical results on the graphene@g- C_3N_4 composite air electrode show a 0.48 V lower charging plateau and a 0.13 V higher discharging plateau than those of pure graphene air electrode, with a discharge capacity of nearly 17300 mAh g^{-1} (composite). Excellent cycling performance, with terminal voltage higher than 2.4 V after 105 cycles at 1000 mAh g^{-1} (composite) capacity, can also be achieved. Therefore, this hybrid material is a promising candidate for use as a high energy, long-cycle-life, and low-cost cathode material for lithium oxygen batteries. (W. B. Luo et al., ***Small*** **11**, 2817 (2015))

Ultrathin MoS_2 nanosheets as anode materials for sodium-ion batteries with superior performance



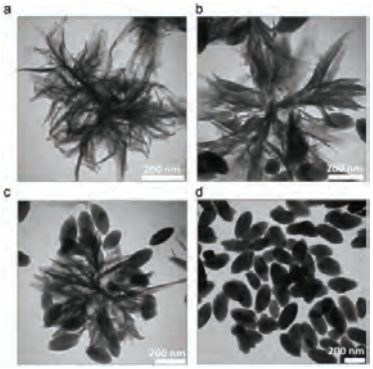
Few-layer MoS_2 nanosheets are successfully synthesized using a simple and scalable ultrasonic exfoliation technique. The thicknesses of the MoS_2 nanosheets ares about 10 nm as measured by scanning electron microscopy (SEM) and atomic force microscopy (AFM). The unique nanosheet architecture renders the high-rate transportation of sodium ions due to the short diffusion paths provided by ultrathin thickness and the large interlayer space within the MoS_2 crystal structure (d (002) = 6.38 Å). When applied as anode materials in sodium-ion batteries, MoS_2 nanosheets exhibit a high, reversible sodium storage capacity and excellent cyclability. The MoS_2 nanosheets also demonstrate good electrochemical performance at high current densities. (D. W. Su et al., ***Advanced Energy Materials*** **5**, 1401205 (2015))

Large-scale synthesis of ordered mesoporous carbon fiber and its application as cathode material for lithium–sulfur batteries



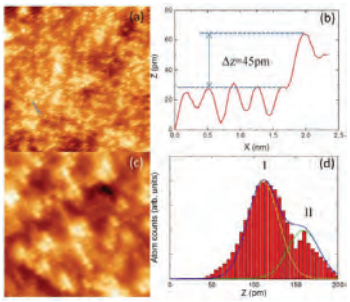
A novel type of one-dimensional ordered mesoporous carbon fiber has been prepared via the electrospinning technique by using resol as the carbon source and triblock copolymer Pluronic F127 as the template. Sulfur is then encapsulated in this ordered mesoporous carbon fibers by a simple thermal treatment. The interwoven fibrous nanostructure has favorably mechanical stability and can provide an effective conductive network for sulfur and polysulfides during cycling. The ordered mesopores can also restrain the diffusion of long-chain polysulfides. The resulting ordered mesoporous carbon fiber sulfur (OMCF-S) composite with 63% S exhibits high reversible capacity, good capacity retention and enhanced rate capacity when used as cathode in rechargeable lithium–sulfur batteries. The resulting OMCF-S electrode maintains a stable discharge capacity of 690 mAh/g at 0.3 C, even after 300 cycles. (H. Q. Wang et al., ***Carbon*** **81**, 782 (2015))

Mesoporous anatase single crystals for efficient $Co^{(2+/3+)}$-based dye-sensitized solar cells



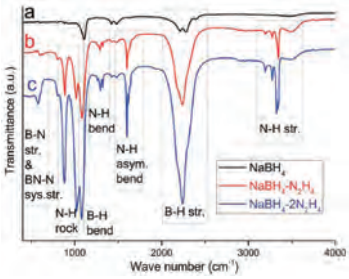
Highly crystalline mesoporous architectures are very promising for a number of applications due to their unique properties arising from their excellent electronic connectivity, structural coherence, mass-transport-efficient channels, and large surface area/porevolume. Herein, we report, for the first time, a facile synthesis approach to mesoporous anatase single crystals (MASCs) with special polyhedral pores(~7 nm).This architecture is employed to construct MK-2-sensitized solar cells using a cobalt redox shuttle, with a maximum efficiency of 8.7% achieved, which is significantly higher than for analogous devices based on commercial Dyesol TiO_2 (6.3%). It is worth emphasizing that not only applications in solar cells, but also in sensing, drug delivery, and photocatalysis may benefit from these innovative MASCs. (J. J. Lin et al., ***Nano Energy*** **11**, 557 (2015))

Pauli-limited effect in the magnetic phase diagram of $FeSe_xTe_{1-x}$ thin films



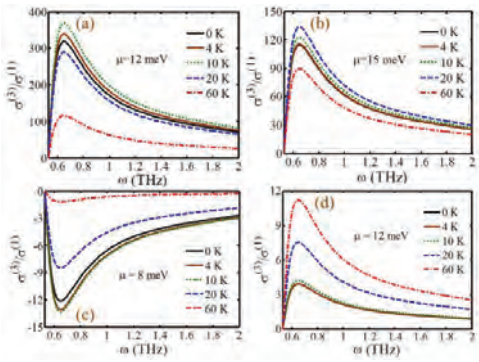
We present a detailed investigation on the doping dependence of the upper critical field $H_{c2}(T)$ of $FeSe_xTe_{1-x}$ thin films ($0.18 \leq x \leq 0.90$) by measuring the electrical resistivity as a function of magnetic field. The $H_{c2}(T)$ curves exhibit a downturn behavior with decreasing temperature in all the samples, owing to the Pauli-limited effect (spin paramagnetic effect). The Pauli-limited effect on the upper critical field can be monotonically modulated by variation of the Se/Te composition. Our results show that Te-doping induced disorder and excess Fe atoms give rise to enhancement of the Pauli-limited effect. (J. C. Zhuang et al., ***Applied Physics Letters*** **107**, 222601 (2015))

Sodium borohydride hydrazinates: synthesis, crystal structures, and thermal decomposition behavior



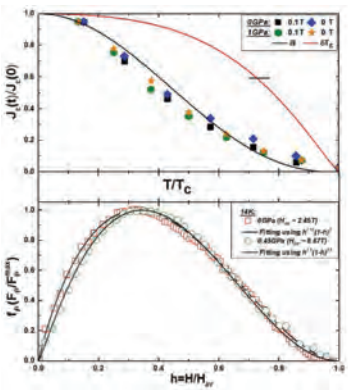
Metallic borohydride hydrazinates are novel boron- and nitrogen-based materials that appear to be promising candidates for chemical hydrogen storage. Herein, sodium borohydride hydrazinates, including $NaBH_4 \cdot N_2H_4$ and $NaBH_4 \cdot 2N_2H_4$, were synthesized via a facile solution synthesis approach based on the solid–liquid reaction between $NaBH_4$ and hydrazine in tetrahydrofuran (THF) solution. The crystal structure of $NaBH_4 \cdot 2N_2H_4$ was solved to a monoclinic structure with unit cell parameters a = 8.4592(2) Å, b = 11.7131(2) Å, c = 6.4584(1) Å, and β = 100.0777(14)°, with space group A1a1 (9). Each Na^+ ion interacts with four neighboring N_2H_4 molecules, leading to the formation of $Na_4[N_2H_4]_4^{4+}$ cationic chains along the a direction. Such cationic chains are surrounded by anions. The $NaBH_4 \cdot N_2H_4$ (x = 1, 2) was characterized by Powder X-ray diffraction (PXRD), Fourier transform infrared spectroscopy (FTIR), thermal gravimetric analysis (TGA), differential scanning calorimetry (DSC), and mass spectroscopy (MS) to obtain a full picture of the relationship of the structure to the decomposition, which will be useful for future work on borohydride hydrazinates or the study of other B–N materials. Furthermore, magnesium borohydride hydrazinates were synthesized by ball milling the sodium borohydride hydrazinates with magnesium borohydride, and their thermal decomposition was investigated as well. (J. F. Mao et al., ***Journal of Materials Chemistry*** *A* **3**, 11269 (2015))

Nonlinear terahertz response of HgTe/CdTe quantum wells



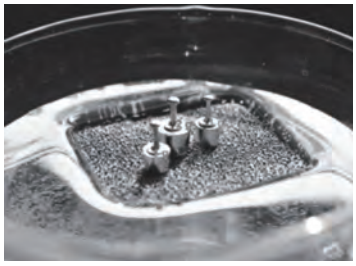
Without breaking the topological order, HgTe/CdTe quantum wells can have two types of bulk band structure: direct gap type (type I) and indirect gap type (type II). We report that the strong nonlinear optical responses exist in both types of bulk states under a moderate electric field in the terahertz regime. Interestingly, for the type II band structure, the third order conductivity changes sign when chemical potentials lies below 10 meV due to the significant response of the hole excitation close to the bottom of conduction band. Negative nonlinear conductivities suggest that HgTe/CdTe quantum wells can find application in the gain medium of a laser for terahertz radiation. The thermal influences on nonlinear optical responses of HgTe/CdTe quantum wells are also studied. (Q. J. Chen et al., ***Applied Physics Letters*** **107**, 081111 (2015))

Giant enhancement in critical current density, up to a hundredfold, in superconducting $NaFe_{0.97}Co_{0.03}As$ single crystals under hydrostatic pressure



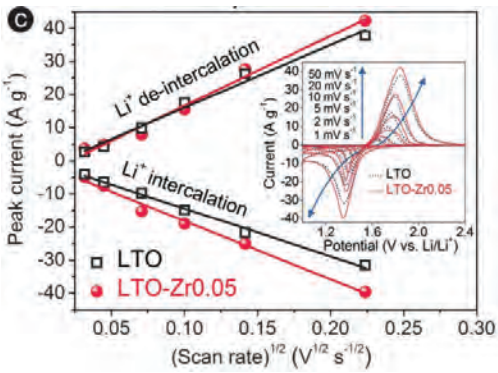
Tremendous efforts towards improvement in the critical current density "*Jc*" of iron based superconductors (FeSCs), especially at relatively low temperatures and magnetic fields, have been made so far through different methods, resulting in real progress. *Jc* at high temperatures in high fields still needs to be further improved, however, in order to meet the requirements of practical applications. Here, we demonstrate a simple approach to achieve this. Hydrostatic pressure can significantly enhance *Jc* in $NaFe_{0.97}Co_{0.03}As$ single crystals by at least tenfold at low field and more than a hundredfold at high fields. Significant enhancement in the in-field performance of $NaFe_{0.97}Co_{0.03}As$ single crystal in terms of pinning force density (*F*p) is found at high pressures. At high fields, the *F*p is over 20 and 80 times higher than under ambient pressure at 12 K and 14 K, respectively, at *P* = 1 GPa. We believe that the Co-doped NaFeAs compounds are very exciting and deserve to be more intensively investigated. Finally, it is worthwhile to say that by using hydrostatic pressure, we can achieve more milestones in terms of high *Jc* values in tapes, wires or films of other Fe-based superconductors. (B. Shabbir et al., ***Scientific Reports*** **5**, 10606 (2015))

Bio-inspired multifunctional metallic foams through the fusion of different biological solutions



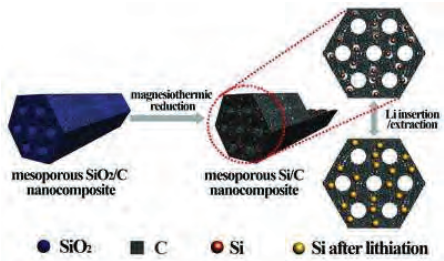
Nature is a school for scientists and engineers. Inherent multiscale structures of biological materials exhibit multifunctional integration. In nature, the lotus, the water strider, and the fl ying bird evolved different and optimized biological solutions to survive. In this contribution, inspired by the optimized solutions from the lotus leaf with superhydrophobic self-cleaning, the water strider leg with durable and robust superhydrophobicity, and the lightweight bird bone with hollow structures, multifunctional metallic foams with multiscale structures are fabricated, demonstrating low adhesive superhydrophobic self-cleaning, striking loading capacity, and superior repellency towards different corrosive solutions. This approach provides an effective avenue to the development of water strider robots and other aquatic smart devices fl oating on water. Furthermore, the resultant multifunctional metallic foam can be used to construct an oil/water separation apparatus, exhibiting a high separation effi ciency and long-term repeatability. The presented approach should provide a promising solution for the design and construction of other multifunctional metallic foams in a large scale for practical applications in the petro-chemical fi eld. Optimized biological solutions continue to inspire and to provide design idea for the construction of multiscale structures with multifunctional integration. (X. Jin et al., ***Advanced Functional Materials*** **24**, 2721 (2014))

Zr^{4+} doping in $Li_4Ti_5O_{12}$ anode for lithium-ion batteries: open Li^+ diffusion paths through structural imperfection



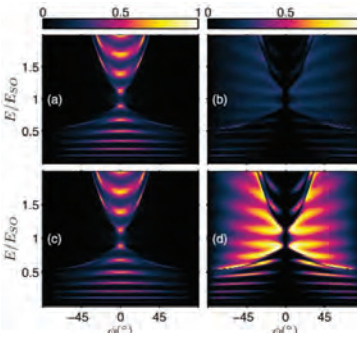
One-dimensional nanomaterials have short Li^+ diffusion paths and promising structural stability, which results in a long cycle life during Li^+ insertion and extraction processes in lithium rechargeable batteries. In this study, we fabricated one-dimensional spinel $Li_4Ti_5O_{12}$ (LTO) nanofibers using an electrospinning technique and studied the Zr^{4+} doping effect on the lattice, electronic structure, and resultant electrochemical properties of Li-ion batteries (LIBs). Accommodating a small fraction of Zr^{4+} ions in the Ti^{4+} sites of the LTO structure gave rise to enhanced LIB performance, which was due to structural distortion through an increase in the average lattice constant and thereby enlarged Li+ diffusion paths rather than changes to the electronic structure. Insulating ZrO_2 nanoparticles present between the LTO grains due to the low Zr^{4+} solubility had a negative effect on the Li^+ extraction capacity, however. These results could provide key design elements for LTO anodes based on atomic level insights that can pave the way to an optimal protocol to achieve particular functionalities. (J. G. Kim et al., ***ChemSusChem*** **7**, 1451 (2014))

Highly reversible and large lithium storage in mesoporous Si/C nanocomposite anodes with silicon nanoparticles embedded in a carbon framework



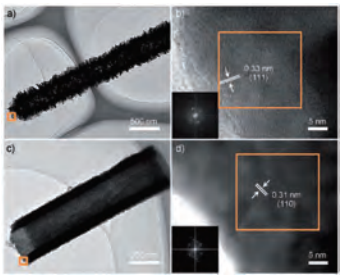
A magnesiothermic reduction approach is designed to synthesize mesoporous Si/C nanocomposites with ultrasmall, uniform silicon nanoparticles (ca. 3 nm) embedded in a rigid mesoporous carbon framework. The resultant mesoporous Si/C nanocomposites present excellent performance with high reversible capacity, good columbic efficiency and rate capability (1500 mAh/g at 2 A/g rate for 1000 cycles), and outstanding cycling stability in lithium-ion battery applications. (R. Y. Zhan et al ***Advanced Materials*** 26, 6749 (2014)

Quantum ratchet in two-dimensional semiconductors with Rashba spin-orbit interaction



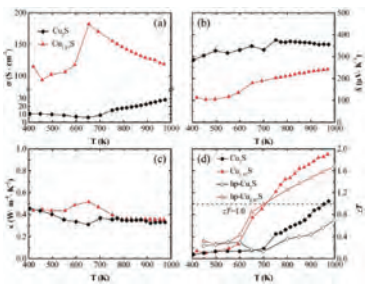
Ratchet is a device that produces direct current of particles when driven by an unbiased force. We demonstrate a simple scattering quantum ratchet based on an asymmetrical quantum tunneling effect in two-dimensional electron gas with Rashba spin-orbit interaction (R2DEG). We consider the tunneling of electrons across a square potential barrier sandwiched by interface scattering potentials of unequal strengths on its either sides. It is found that while the intra-spin tunneling probabilities remain unchanged, the inter-spin-subband tunneling probabilities of electrons crossing the barrier in one direction is unequal to that of the opposite direction. Hence, when the system is driven by an unbiased periodic force, a directional flow of electron current is generated. The scattering quantum ratchet in R2DEG is conceptually simple and is capable of converting a.c. driving force into a rectified current without the need of additional symmetry breaking mechanism or external magnetic field. (Y. S. Ang et al., ***Scientific Reports*** **5**, 7872 (2015))

Room-temperature synthesis of $Cu_{2-x}E$ (E = S, Se) nanotubes with hierarchical architecture as high-performance counter electrodes of quantum-dot-sensitized solar cells



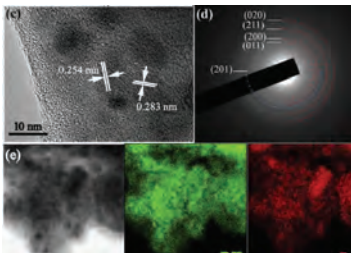
Copper chalcogenide nanostructures (e.g. onedimensional nanotubes) have been the focus of interest because of their unique properties and great potential in various applications. Their current fabrications mainly rely on high-temperature or complicated processes. Here, with the assistance of theoretical prediction, we prepared $Cu_{2-x}E$ (E= S, Se) micro-/nanotubes (NTs) with a hierarchical architecture by using copper nanowires (Cu NWs), stable sulfur and selenium powder as precursors at room temperature. The influence of reaction parameters (e.g. precursor ratio, ligands, ligand ratio, and reaction time) on the formation of nanotubes was comprehensively investigated. The resultant $Cu_{2-x}E$ (E=S, Se) NTs were used as counter electrodes (CE) of quantum-dot-sensitized solar cells (QDSSCs) to achieve a conversion efficiency (η) of 5.02 and 6.25 %, respectively, much higher than that of QDSSCs made with Au CE (η=2.94 %). (X. Q. Chen et al., ***Chemistry – A European Journal*** **21**, 1055 (2015))

High thermoelectric and mechanical performance in highly dense $Cu_{2-x}S$ bulks prepared by a melt solidification technique



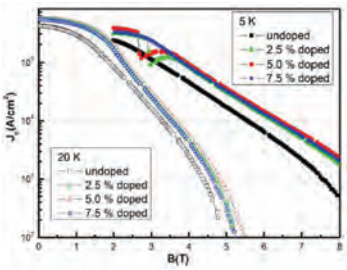
Highly dense $Cu_{2-x}S$ bulks, fabricated by a melt-solidification technique, show high thermoelectric performance with zT of ~1.9 at 970 K. The $Cu_{2-x}S$ bulks show good thermal heat flow and diffusivity stability, and they exhibit excellent mechanical properties, with hardness of _1 GPa. Density functional theory calculations indicate that $Cu_{2-x}S$ is an intrinsic p-type conductor. (L. L. Zhao et al., ***Journal of Materials Chemistry A*** **3**, 9432 (2015))

Cobalt phosphide as a new anode material for sodium storage



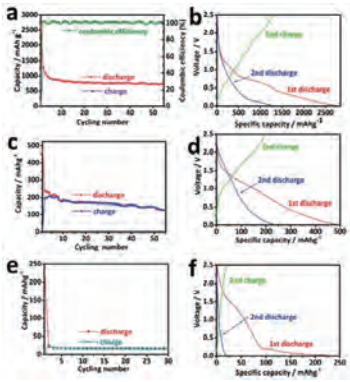
A novel anode material for sodium ion batteries - nanosized CoP particles - was synthesized by a facile and productive ball-milling method. The CoP was tested as an anode candidate for sodium ion batteries. It delivered a high initial specific capacity of 770 mAh g^{-1}, and excellent rate capability, demonstrating that CoP is a promising anode candidate for sodium ion storage. Ex-situ X-ray photoelectron spectroscopy and scanning transmission electron microscopy were carried out to investigate the sodium storage mechanism of CoP. (W. J. Li et al., ***Journal of Power Sources*** **294**, 627 (2015))

Improvements in the dispersion of nanosilver in a MgB_2 matrix through a graphene oxide net



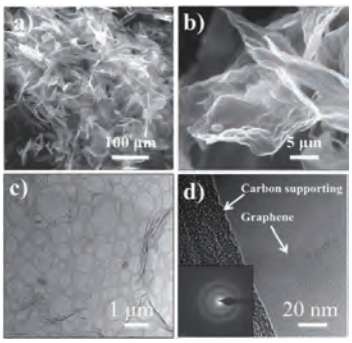
The effects of graphene oxide (GO) addition on the dispersion of nanosilver (Ag) in an MgB_2 matrix were studied using bulk samples prepared through a diffusion process. The influence of the dispersion of Ag and Ag/GO particles on the critical current density (Jc) of MgB_2 was also investigated. GO has emerged as an excellent dopant which can significantly improve both the low- and high-field performance of MgB_2 due to its capability to improve intergrain connectivity (GO) and inter- and intragrain pinning (GO and AgMg). The addition of nanosize Ag particles also results in an improvement of vortex pinning, and at the same time, it offers the advantage of preventing the loss of Mg during the sintering process. It is found that the dispersion of nanosilver in the presence of GO results in significant improvements in the critical current density in MgB_2, particularly at high magnetic fields, due to improved intergrain connectivity and flux pinning. The use of the GO net as a platform for doping MgB_2 in our case with Ag yielded a 10-fold-better critical current density (Jc) than standard Ag doping at 9 T and 5 K. Even without sophisticated processes, we obtained a Jc result of 10^4 A/cm^2 at 9 T and 5 K, which is one of the best ever achieved (M. Mustapic et al., ***Journal of Physical Chemistry C*** **119**, 10631 (2015))

A phosphorus/N-doped carbon nanofiber composite as an anode material for sodium-ion batteries



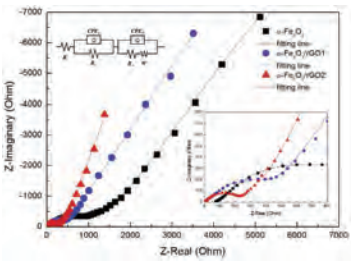
Sodium-ion batteries (SIBs) have been attracting intensive attention at present as the most promising alternative to lithium-ion batteries in large-scale electrical energy storage applications, due to the low-cost and natural abundance of sodium. Elemental phosphorus (P) is a very promising anode material for SIBs, with the highest theoretical capacity of 2596 mAh g^{-1}. Recently, there have been many efforts devoted to phosphorus anode materials for SIBs. As pure red phosphorus cannot react with Na reversibly, many attempts to prepare composite materials containing phosphorus have been reported. Here, we report the facile preparation of a red phosphorus/N-doped carbon nanofiber composite (P/NCF) that can deliver a reversible capacity of 731 mAh g^{-1} in sodium-ion batteries (SIBs), with a capacity retention of 57.3% over 55 cycles. Our results suggest that it would be a promising anode candidate for SIBs with a high capacity and low cost. (B. Y. Ruan et al., ***Journal of Materials Chemistry A*** **3**, 19011 (2015))

High-performance sodium ion batteries based on a 3D anode from nitrogen-doped graphene foams



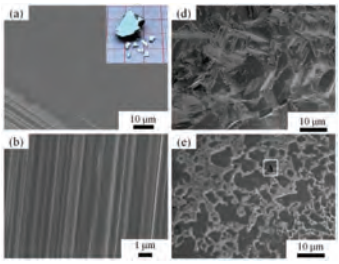
A 3D N-doped graphene foam with a 6.8 at% nitrogen content is prepared by annealing a freeze-dried graphene oxide foam in ammonia. It is used as an anode in sodium ion batteries to deliver a high initial reversible capacity of 852.6 mAh g^{-1} at 1 C between 0.02 and 3 V with a long-term retention of 69.7% after 150 cycles. (J. T. Xu et al., ***Advanced Functional Materials*** **27**, 2042 (2015))

Rapid synthesis of α-Fe_2O_3/rGO nanocomposites by microwave autoclave as superior anodes for sodium-ion batteries



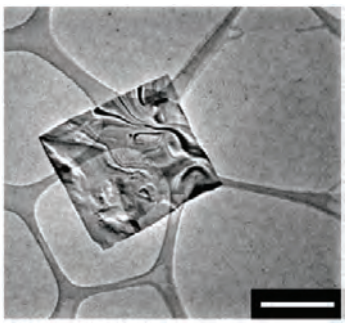
α-Fe_2O_3/reduced graphene oxide (rGO) nanocomposites were successfully synthesized within 15 min through a facile, environmentally friendly microwave hydrothermal method. From field emission scanning electron microscopy and transmission electron microscopy, it can be determined that the α-Fe_2O_3 nanoparticles, around 50 nm in diameter, are uniformly anchored on the graphene nanosheets. The asobtained α-Fe_2O_3/rGO nanocomposites were applied as anode materials in sodium-ion batteries, which could deliver capacity of ~310 mAh g^{-1} after 150 cycles at 100 mA g^{-1}. (Z. J. Zhang et al., ***Journal of Power Sources*** **280**, 107 (2015))

Superior intrinsic thermoelectric performance with zT of 1.8 in single-crystal and melt-quenched highly dense $Cu_{2-x}Se$ bulks



Practical applications of the high temperature thermoelectric materials developed so far are partially obstructed by the costly and complicated fabrication process. In this work, we put forward two additional important properties for thermoelectric materials, high crystal symmetry and congruent melting. We propose that the recently discovered thermoelectric material $Cu_{2-x}Se$, with figure of merit, zT, over 1.5 at T of ~1000 K, should meet these requirements, based on our analysis of its crystal structure and the Cu-Se binary phase diagram. We found that its excellent thermoelectric performance is intrinsic, and less dependent on grain size, while highly dense samples can be easily fabricated by a melt-quenching approach. Our results reveal that the melt-quenched samples and single crystals exhibit almost the same superior thermoelectric performance, with zT as high as 1.7–1.8 at T of ~973 K. Our findings not only provide a cheap and fast fabrication method for highly dense $Cu_{2-x}Se$ bulks with superior thermoelectric performance, paving the way for possible commercialization of $Cu_{2-x}Se$ as an outstanding component in practical thermoelectric modules, but also provide guidance in searching for new classes of thermoelectric systems with high crystal symmetry or further improving the cost performance of other existing congruent-melting thermoelectric materials. (L. L. Zhao et al., ***Scientific Reports*** **5**, 7671 (2015))

Modulation of photocatalytic properties by strain in 2D BiOBr nanosheets



BiOBr nanosheets with highly reactive {001} facets exposed were selectively synthesized by a facile hydrothermal method. The inner strain in the BiOBr nanosheets has been tuned continuously by the pH value. The photocatalytic performance of BiOBr in dye degradation can be manipulated by the strain effect. The low-strain BiOBr nanosheets show improved photocatalytic activity. Density functional calculations suggest that strain can modify the band structure and symmetry in BiOBr. The enhanced photocatalytic activity in low-strain BiOBr nanosheets is due to improved charge separation attributable to a highly dispersive band structure with an indirect band gap. (H. F. Feng et al., ***ACS Applied Materials & Interfaces*** **7**, 27592 (2015))

Selected Refereed Publications

1. S. Aminorroaya-Yamini, D. R. G. Mitchell, Z. M. Gibbs, R. Santos, V. Patterson, S. Li, Y. Z. Pei, S. X. Dou, and G. J. Snyder, "Heterogeneous distribution of sodium for high thermoelectric performance of p-type multiphase lead-chalcogenides", ***Advanced Energy Materials*** 5, 1501047 (2015); (IF: 16.146)
2. Y. S. Ang, Z. S. Ma, and C. Zhang, "Quantum ratchet in two-dimensional semiconductors with Rashba spin-orbit interaction", ***Scientific Reports*** 5, 7872 (2015); (IF: 5.578)
3. Y. Bai, C. Han, X. O. Chen, H. Yu, X. Zong, Z. Li, and L. Z. Wang, "Boosting the efficiency of quantum dot sensitized solar cells up to 7.11% through simultaneous engineering of photocathode and photoanode", ***Nano Energy*** 13, 609 (2015); (IF: 10.325)
4. S. Barua, M. S. Al Hossain, Z. Q. Ma, D. Patel, M. Mustapic, M. Somer, S. Acar, I. Kokal, T. Cetner, D. Gajda, and S. X. Dou, "Superior critical current density obtained in MgB_2 bulks through low-cost carbon-encapsulated boron powder", ***Scripta Materialia*** 104, 37 (2015); (IF: 3.224)
5. Y. J. Cai, Y. D. Huang, X. C. Wang, D. Z. Jia, W. K. Pang, Z. P. Guo, Y. P. Du, and X. C. Tang, "Facile synthesis of $LiMn_2O_4$ octahedral nanoparticles as cathode materials for high capacity lithium ion batteries with long cycle life", ***Journal of Power Sources*** 278, 574 (2015); (IF: 6.217)
6. J. Chen, Y. Du, Z. Li, W. B. Li, B. J. Feng, J. L. Qiu, P. Cheng, S. X. Dou, L. Chen, and K. H. Wu, "Delocalized surface state in epitaxial Si (111) film with spontaneous root 3 x root 3 superstructure", ***Scientific Reports*** 5, 13590 (2015); (IF: 5.578)
7. M. J. Chen, J. P. Yang, Y. Liu, W. Li, J. W. Fan, X. Q. Ran, W. Teng, Y. Sun, W. X. Zhang and G. M. Li, "TiO_2 interpenetrating networks decorated with SnO_2 nanocrystals: enhanced activity of selective catalytic reduction of NO with NH_3", ***Journal of Materials Chemistry A*** 3, 1405 (2015); (IF: 7.443)
8. Q. J. Chen, M. Sanderson, and C. Zhang, "Nonlinear terahertz response of HgTe/CdTe quantum wells", ***Applied Physics Letters*** 107, 081111 (2015); (IF: 3.302)
9. W. D. Chen, Z. G. Huang, G. T. Wu, T. He, Z. Li, J. E. Chen, Z. P. Guo, H. K. Liu, and P. Chen, "Guanidinium octahydrotriborate: an ionic liquid with high hydrogen storage capacity", ***Journal of Materials Chemistry A*** 3, 11411 (2015); (IF: 7.443)
10. X. Q. Chen, Z. Li, and S. X. Dou, "Ambient facile synthesis of gram-scale copper selenide nanostructures from commercial copper and selenium powder", ***ACS Applied Materials & Interfaces*** 7, 13295 (2015); (IF: 6.723)
11. M. F. M. Din, J. L. Wang, Z. X. Cheng, S. X. Dou, S. J. Kennedy, M. Avdeev, and S. J. Campbell, "Tuneable magnetic phase transitions in layered $CeMn_2Ge_{2-x}Si_x$ compounds", ***Scientific Reports*** 5, 11288 (2015); (IF: 5.578)
12. V. H. Duong, H. A. Bastawrous, K. C. Lim, K. W. See, P. Zhang, and S. X. Dou, "Online state of charge and model parameters estimation of the $LiFePO_4$ battery in electric vehicles using multiple adaptive forgetting factors recursive least-squares", ***Journal of Power Sources*** 296, 215 (2015); (IF: 6.217)
13. H. F. Feng, Z. F. Xu, L. Wang, Y. X. Yu, D. Mitchell, D. Cui, X. Xu, J. Shi, T. Sannomiya, and Y. Du, "Modulation of photocatalytic properties by strain in 2D BiOBr nanosheets", ***ACS Applied Materials & Interfaces*** 7, 27592 (2015); (IF:6.723)
14. X. W. Gao, Y. F. Deng, D. Wexler, G. H. Chen, S. L. Chou, H. K. Liu, Z. C. Shi, and J. Z. Wang, "Improving the electrochemical performance of the $LiNi_{0.5}Mn_{1.5}O_4$ spinel by polypyrrole coating as a cathode material for the lithium-ion battery", ***Journal of Materials Chemistry A*** 3, 404 (2015); (IF: 7.443)
15. S. Gong, T. Zhao, M. Sanderson, M. Hu, R. B. Zhong, X. X. Chen, P. Zhang, C. Zhang, and S. G. Liu, "Transformation of surface plasmon polaritons to radiation in graphene in terahertz regime", ***Applied Physics Letters*** 106, 223107 (2015); (IF: 3.302)
16. C. Han, Z. Li, G. Q. Lu, and S. X. Dou, "Robust scalable synthesis of surfactant-free thermoelectric metal chalcogenide nanostructures", ***Nano Energy*** 15, 193 (2015); (IF: 10.325)
17. W. B. Hua, X. D. Guo, Z. Zheng, Y. J. Wang, B. H. Zhong, B. Fang, J. Z. Wang, S. L. Chou, and H. Liu, "Uncovering a facile large-scale synthesis of $LiNi_{1/3}Co_{1/3}Mn_{1/3}O_2$ nanoflowers for high power lithium-ion batteries", ***Journal of Power Sources*** 275, 200 (2015); (IF: 6.217)
18. S. M. Hwang, S. Y. Kim, J. G. Kim, K. J. Kim, J. W. Lee, M. S. Park, Y. J. Kim, M. Shahabuddin, Y. Yamauchi, and J. H. Kim, "Electrospun manganese-cobalt oxide hollow nanofibres synthesized via combustion reactions and their lithium storage performance", ***Nanoscale*** 7, 8351 (2015); (IF: 7.394)
19. I. Y. Jeon, M. J. Ju, J. T. Xu, H. J. Choi, J. M. Seo, M. J. Kim, I. T. Choi, H. M. Kim, J. C. Kim, J. J. Lee, H. K. Liu, H. K. Kim, S. X. Dou, L. M. Dai, and J. B. Baek, "Edge-fluorinated graphene nanoplatelets as high performance electrodes for dye-sensitized solar cells and lithium ion batteries", ***Advanced Functional Materials*** 25, 1170 (2015); (IF: 11.805)
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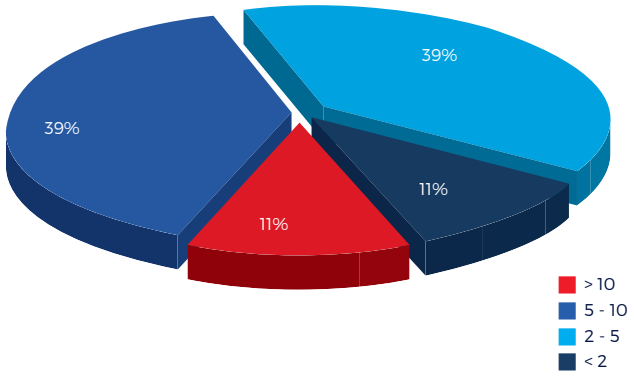
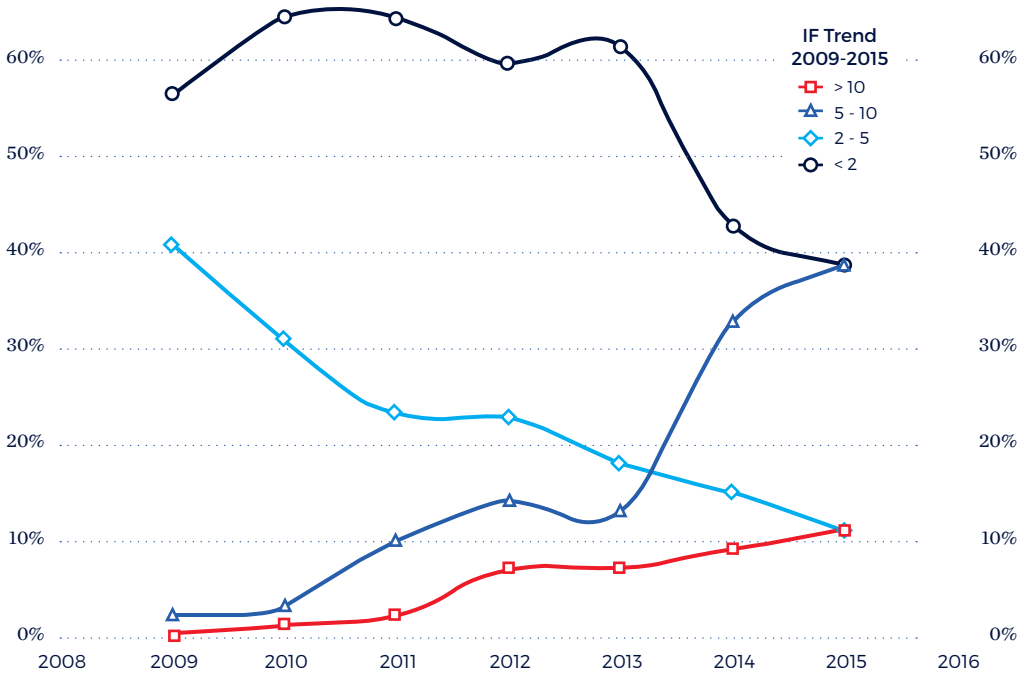


2015 Publication Statistics



Funding 2015

AUSTRALIAN RESEARCH COUNCIL GRANTS

ARC DISCOVERY SCHEME GRANTS

Chief Investigators	Title	2015 Funding
X. L. Wang, C. Zhang, R. A. Lewis, Q. K. Xue, A. Hoffmann, F. Klose	Electron and spin transport in topological insulators	$140,000
Z. Li, M. Lu	Nanostructure engineering of semiconductor nanowires for high performance thermoelectric	$100,000
C. Zhang, X. L. Wang, R. A. Lewis, Q. L. Bao, J. Horvat	Novel terahertz electronics, photonics and plasmonics in high- mobility, low-dimensional electronic systems (HMLDES)	$140,000
J. Z. Wang, J. Chen, S. L. Chou, H. K. Liu, H. S. Zhou, X. L. Wang	Lithium-ion air batteries with non-flammable ionic liquid–based electrolytes	$140,000
S. X. Dou, Y. Du, X. Xu, G. Peleckis, J. Scott, J. H. Ye, W. C. Hao, K. S. Liu, P. Cheng	Design and exploration of novel p-block materials for solar energy conversion	$145,000
Z. P. Guo, Z. G. Huang, H. K. Liu, X. B. Yu, Q. F. Gu	Development of highly regenerable ammonia-borane and related boron nitride-based hydrides with low cost for hydrogen storage	$120,000
Total		$785,000

ARC FUTURE FELLOWSHIPS

Chief Investigators	Title	2015 Funding
J. H. Kim	Development of a solid nitrogen cooled magnesium diboride (MgB_2) magnet for persistent-mode operation	$86,000
X. L. Wang	Electronic topological materials	$246,000
S. J. Zhang	Lead-free bismuth based dielectric materials for energy storage	$222,000
Total		$554,000

ARC DECRA FELLOWSHIPS

Chief Investigators	Title	2015 Funding
M. S. A. Hossain	Rational design of a new generation magnesium diboride superconducting rotor coil suitable for offshore low-cost wind turbine generators	$125,000
S. Aminorroaya-Yamini	Nano-engineered, cost-effective lead chalcogenides to boost performance of mid-range temperature thermoelectric materials	$125,000
Z. Q. Ma	Microstructure design of second generation MgB_2 superconducting wires for enhancement of critical current density	$124,000
Total		$374,000

ARC LIEF GRANTS		
Chief Investigators	Title	2015 Funding
S. X. Dou, G. Peleckis, X. L. Wang, J. B. Yi, Y. W. Mai, L. H. Li, R. A. Lewis, Y. Chen, G. Spinks	New generation cryogen-free Physical Property Measurement System	$420,000
Total		$420,000

ARC LINKAGE PROJECTS		
Chief Investigators	Title	2015 Funding
S. L. Chou, J. Z. Wang, H. K. Liu, D. Wexler, Y. M. Kang	Development of novel composite anode materials combined with new binders for high energy, high power and long life lithium-ion batteries	$65,000
S. X. Dou, S. Li, W. X. Li, C. Zhang, S. Aminorroaya-Yamini	New generation high efficiency thermoelectric materials and modules for waste heat recovery from steelworks	$160,000
Total		$225,000
2015 Australian Research Council Grants Total:		$2,238,000

AUTO CRC GRANTS / AUTO CRC PROJECTS		
Chief Investigators	Title	2015 Funding
S. X. Dou, G. X. Wang	1-108: Lithium air battery for electric vehicles	$78,000
S. X. Dou, Z. P. Guo	1-110: Design and prototype of on-vehicle battery management system for electrical vehicles	$78,000
S. X. Dou, G. X. Wang, H. K. Liu	1-111: Development of advanced electrode and electrolytes for LIB	$480,000
S. X. Dou, K. W. See	1-112: Battery charge, mechanical and thermal management system development	$356,000
S. X. Dou, K. W. See	1-113: Lithium ion battery module packaging and testing	$208,000
S. X. Dou, C. Zhang, S. Aminorroaya-Yamini	1-203: Thermoelectric – efficient energy recovery in light and heavy vehicles	$154,000
H. K. Liu, Z. P. Guo, J. Z. Wang, J. H. Kim, K. Konstantinov, S. L. Chou	1-117: High energy anode materials for lithium ion batteries	$113,000
Total		$1,467,000
AUTO CRC SCHOLARSHIPS		
H. K. Liu, S.X. Dou	4-102: The study of carbon based battery materials	$33,000
J. Z. Wang, S.X. Dou	4-103: S-Carbon composite cathode material for Li-S battery	$33,000
K. Konstantinov, S.X. Dou	4-104: Conducting polymer coated graphene oxide nanocomposites for supercapacitor application	$33,000
Z. P. Guo, S. X. Dou	4-105: Fabrication & characterisation of graphene & graphene oxide composites for application in supercaps & Li-ion batteries	$33,000
Total		$132,000
2015 Auto CRC Grants Total:		$1,599,000

OTHER GRANTS

Chief Investigators	Title	2015 Funding
S. Aminorroaya-Yamini, S. Kennedy, M. Avdeev, A. Manettas	Neutron diffraction study of multiphase quaternary Pb-chalcogenide thermoelectric materials	$44,000
S. X. Dou, K. W. See	Diesel-free environment for underground coal mines	$110, 000
H. K. Liu, Z. P. Guo, J. Z. Wang, J. H. Kim, K. Konstantinov, S. L. Chou	High energy anode materials for lithium ion batteries	$100,000
Total		$254,000

UOW GRANTS & ARC NEAR-MISS GRANTS

Chief Investigators	Title	2015 Funding
S. X. Dou et al.	Exploration of novel two-dimensional silicene for electronic applications	$15,000
Z. G. Huang et al.	Liquid hydrogen carriers for future energy storage and delivery	$15,000
M. S. A. Hossain	Magnetically triggered mechanoselective channels for liposomal drug delivery	$18,000
J. L. Wang	Texture-induced enhancement of physical response in melt-spun ribbons and thisn films of intermetallic compounds	$11,000
K. Konstantinov	Structural and chemical surface characterisation of functionalised theanostic core/shell ceramic nanostructures for cancer therapy	$10,000
Total		$69,000
UOW Support (Performance, Management, PGS Maintenance)		$300,000
2015 Other Grants Total:		$623,000
Total Funding 2015		$4,580,000

Members of the Australian Renewable Energy Agency (ARENA) visiting ISEM before submission of successful funding application on sodium-ion batteries

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