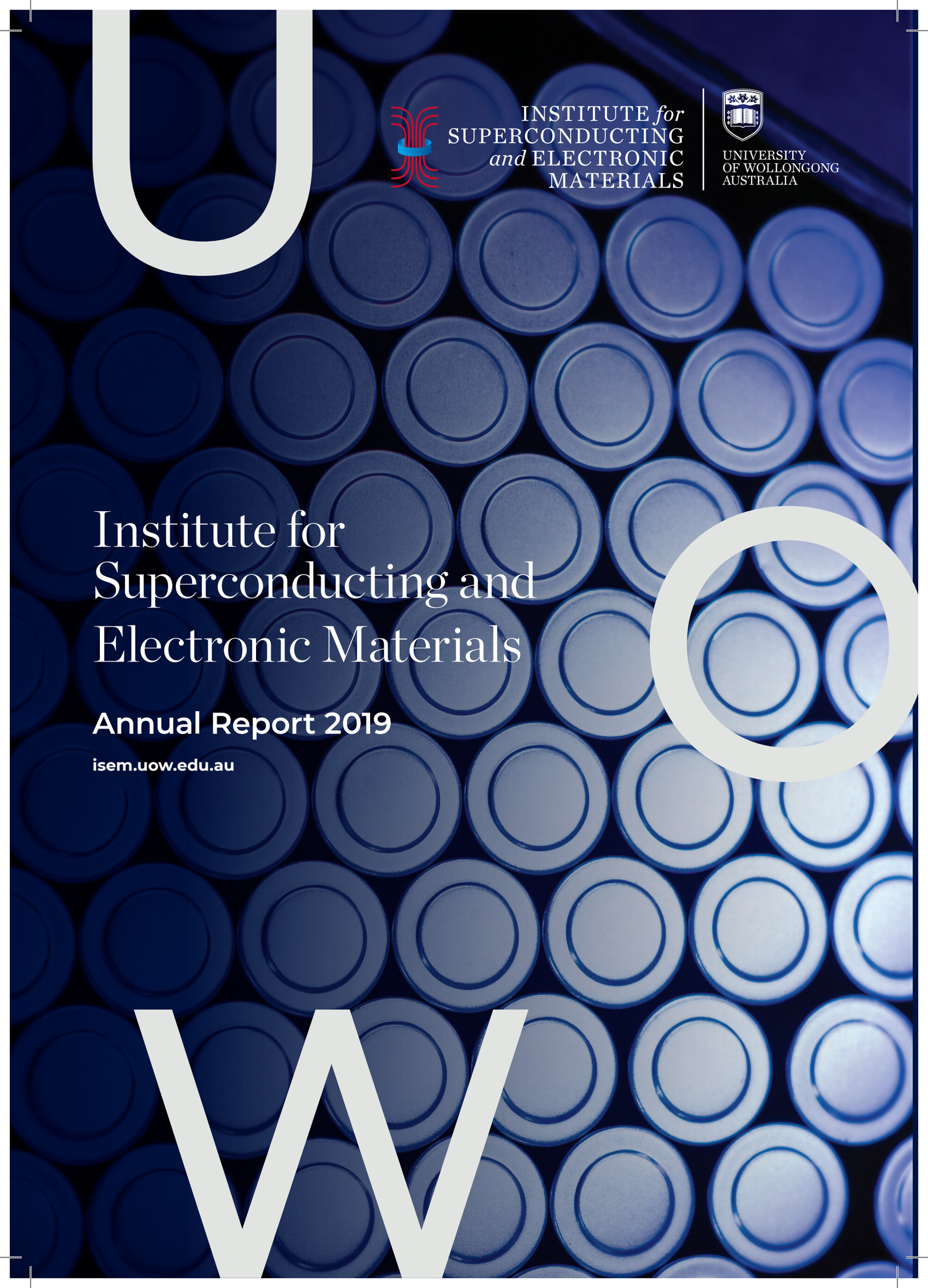


INSTITUTE *for* SUPERCONDUCTING *and* ELECTRONIC MATERIALS

UNIVERSITY OF WOLLONGONG AUSTRALIA

Institute for Superconducting and Electronic Materials

Annual Report 2019

isem.uow.edu.au

Contents

Director's Report

Dear All

I am very pleased to present you with The Institute for Superconducting and Electronic Materials 2019 Annual Report.

2019 was a special year for ISEM as it marked the change of leadership team at ISEM and was also the most successful year for ISEM in many aspects. In the 2019 QS World University Rankings, UOW, for the first time since 2013, has achieved its aspirational goal of reaching top 1% of universities worldwide. ISEM made great contributions to UOW's reputation and its new ranking position. I would like to highlight some of the new changes and main achievements.

We have revisited and redefined ISEM's vision for the future: This vision is to be a key research intensive unit at UOW delivering high impact training, high impact research, high impact applications, high impact collaborations, high impact gender equality and diversity and high impact community engagement.

The review of ISEM's internal research structure/programs resulted in the formulation of six main research strengths: 1) Superconductors and Low Energy Materials; 2) Advanced Energy Materials Science and Technology; 3) Advanced Piezoelectric and Magnetic Materials; 4) Advanced Thin Film Science and Technology; 5) Advanced THz Science and Photonics; 6) Advanced Materials for Bio and Health Science. These research strengths are supported by ten new research programs and are led by highly experienced and dedicated Program Coordinators.

20 PhD students graduated in 2019, bringing our total ISEM PhD completions to nearly 220. As highly-skilled Early-Career Researchers (ECRs), many of our graduates have secured post-doctoral or other positions in Australia and overseas. Many of them have stayed in ISEM to continue their contributions to ISEM and UOW.

ISEM performed exceptionally well in terms of publications in both volume and quality. 2019 marked the year of our first publications in Science and other top Nature and Science sister journals. ISEM published over 400 papers, with an average Impact Factor greater than 10.06.

2019 saw the high standard of research at ISEM recognised internationally. The 2019 Clarivate Analytics ISI Highly Cited Researchers list included seven UOW researchers in total, with five of those representing ISEM: Distinguished Professor Shi Xue Dou, Distinguished Professor Hua Kun Liu, Distinguished Professor Zaiping Guo, Distinguished Professor Yoshio Bando, and Professor Shulei Chou. Professor Shujun Zhang was also inducted as a Fellow of The American Ceramic Society – recognising his significant contribution to the field.

In 2019, ISEM continued its success in attracting competitive funding from the Australian Research Council (ARC), Federal and State Governments, and National and International industry and funding organisations such as Coal Services Council, US Navy, and Defence Science and Technology Organisation. This year, ISEM has secured two ARC DECRA Fellowships and two ARC Discovery Projects. The total funding received by ISEM for these projects is $2.075M, approximately 20% of UOW's total ARC research grant success in 2019. In close collaboration with our industry partners on the ARENA-funded S4 project, we have made a number of important advances towards delivering a fully-functional sodium-ion battery based energy storage solution.

Dr. Khay See attracted a Global Innovation Linkages Grant from the Australian Federal Government with total funding over $1.5M, bringing together NPG and Shanghai Electrics Industry Partners to target full-scale battery-based machines for the mining industry – which has great potential to deliver breakthrough technological advances in this sector. ISEM's pioneering study on a new class of piezoelectric materials has found great potential for deployment in underwater acoustic applications and these materials have been successfully commercialised for use in high performance medical imaging and other applications. The industrial partners in this industry-leading research include Thales Australia, Ceracomp (Korea), TRS Technologies (USA), Ethicon – a subsidiary of Johnson-Johnson (USA), Meggitt (USA), and Endevco (USA).

As a member of the global research community, we continued our successful outreach to National and International Collaborators in 2019 through series of events including workshops, invited presentations and seminars, visiting fellowship programs, and student exchange. This year we hosted the 2019 International Symposium on Future Materials, which was held at UOW's Innovation Campus. This symposium was one of the largest and most distinguished international events that ISEM has held in its 25-year history, attracting more than 250 delegates, guests and visitors from China, USA, Norway, Japan, Korea, Taiwan with Singapore, and Hong Kong. This acclaimed event saw world leaders in a broad range of research fields join us in Wollongong to discuss the latest developments in materials science – with many attendees commending ISEM for hosting such an exceptional event.

ISEM has continued its high-profile leadership within Australia's research community, including through its ongoing role as a node of ARC Centre of Excellence in Future Low-Energy Electronics Technology (FLEET) – a role that has facilitated the establishment of many new National and International collaborations. Two Joint Centers - Beihang (China) – UOW Joint Centre and the NIMS (Japan) - UOW Joint Centre – were both extended for a second three-year term. In addition, ISEM Academic Staff were highly proactive in establishing collaborations and organising MOUs with many other prestigious research teams worldwide.

Our Academic Staff have further enhanced their international reputation, as evidenced by their appointments as Honorary Professors, Members of Editorial Boards, and Advisory Boards at prestigious universities and journals. Since its inception in 1994, ISEM has secured 65 ARC Fellowships, more than 40% of all ARC Fellowships at UOW in that period. Our senior academic researchers have continued their leading roles across their relevant disciplines, while our ECRs have continued to be exceptionally proactive in establishing their leadership and research standing.

In 2019, ISEM Founding Director Distinguished Professor Shi Xue Dou was inducted as a Member of the Order of Australia (AM) by the Australian Government. I would like to give my special thanks to Professor Dou for his great contribution to ISEM over the many years. The significant contributions ISEM has made to UOW were recognised in the 2019 UOW Vice Chancellor's Awards, with Professor Dou and Associate Professor Josip Horvat receiving awards for 25 years of service; Professor Dou and Professor Hua Kun Liu receiving a Highly Commended in the Vice-Chancellor's Award For Outstanding Achievement In Research Partnership & Impact for their partnership with the China BAOWU Steel Group; and Professor Zaiping Guo sharing the 2019 Vice-Chancellor's Research Excellence Award For Researcher Of The Year. The leadership, contributions and international standing of ISEM staff was also recognised through promotions to Senior Research Fellow (Wenping Sun), Associate Professor (Yi Du), Professor (Shulei Chou), and Distinguished Professor (Xiaolin Wang).

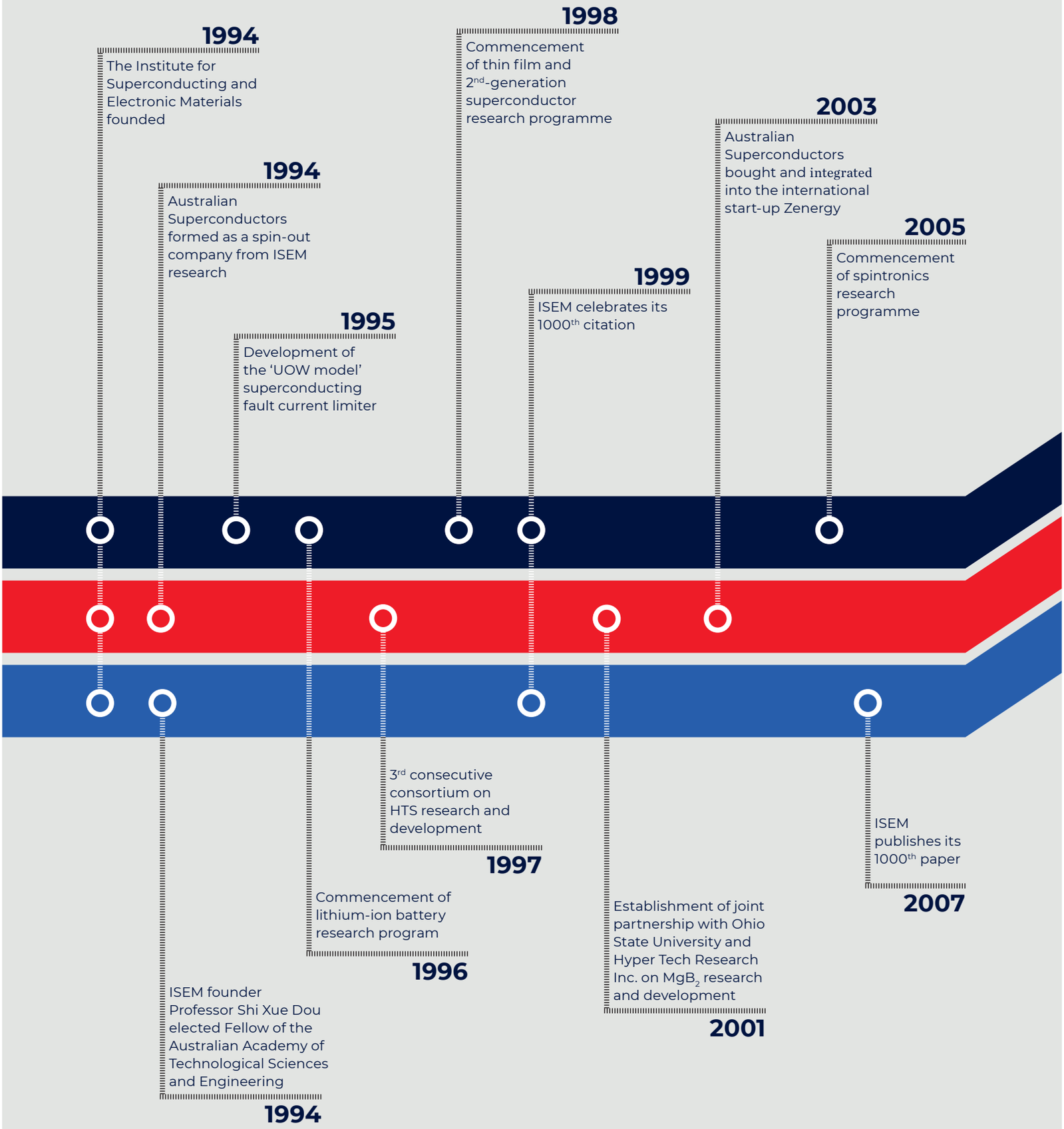
ISEM is visionary in the development of its research programs by incorporation of emerging fields of innovation. ISEM is a comprehensive, multi-disciplinary and international flagship institute in materials science and applications. ISEM has made substantial contributions to Australia and UOW in research achievements, recognised in outstanding performance across multiple university ranking schemes. Our research strategy is focused on motivating researchers at all levels to achieve their highest level of leadership, maintain an open door policy, excel in broad networking practices, and have strong drive to engage with industry partners.

I would like to take this opportunity to sincerely acknowledge the strong support ISEM has received from the UOW Executive, AIIM staff, faculty, administration staff, technical staff, WHS staff, commercial management staff, industry partners, ISEM Alumni, and academic collaborators. I would also like to express my gratitude to ISEM staff, students, honorary fellows, and visitors for their dedication and hard work.

I am certain that ISEM will continue its success in 2020 and will play a major role in maintaining UOW's position in the top 1% universities worldwide.

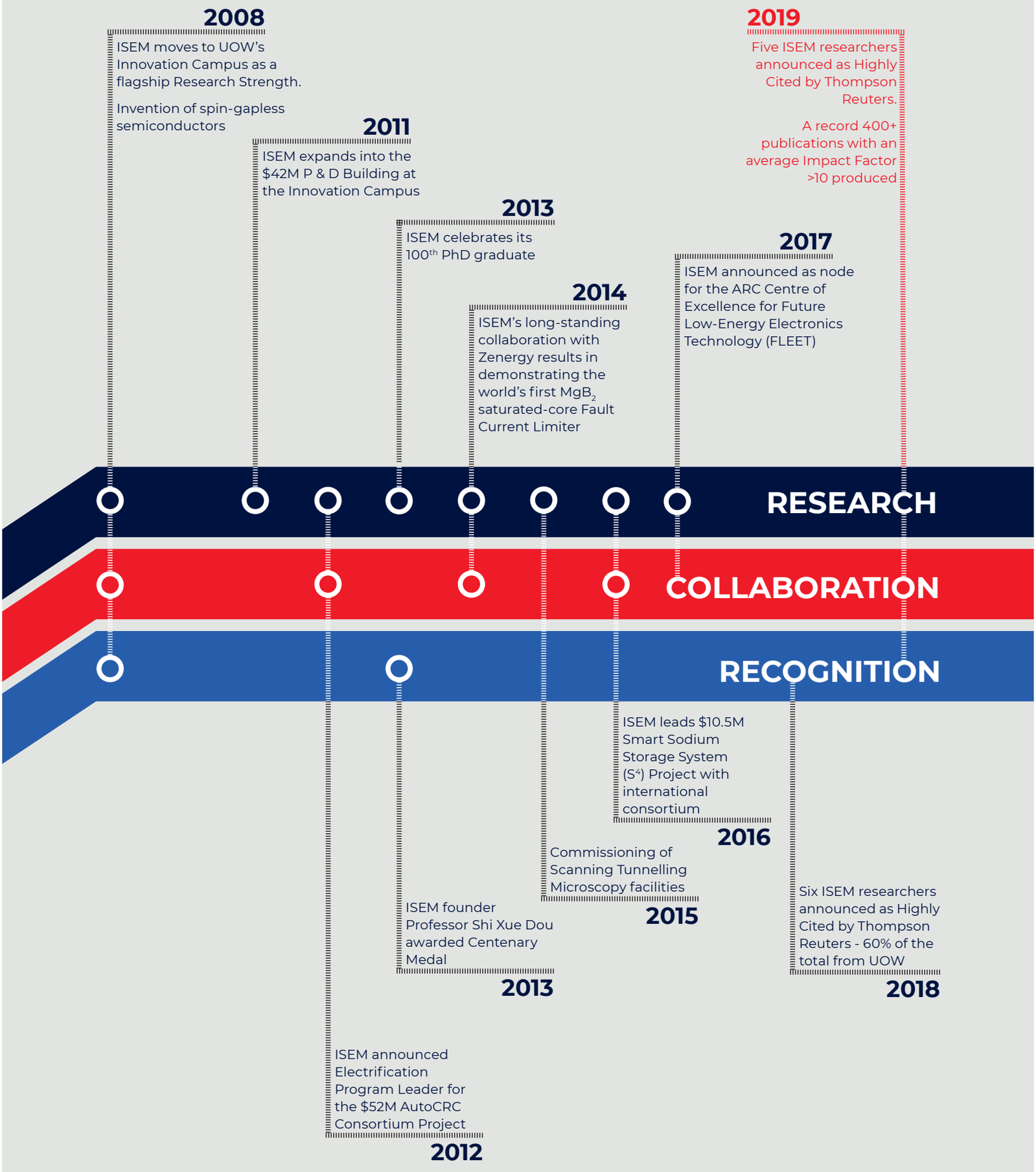
Xiaolin Wang
Director and Distinguished Professor

25+ Years of Success



THE EARLY YEARS

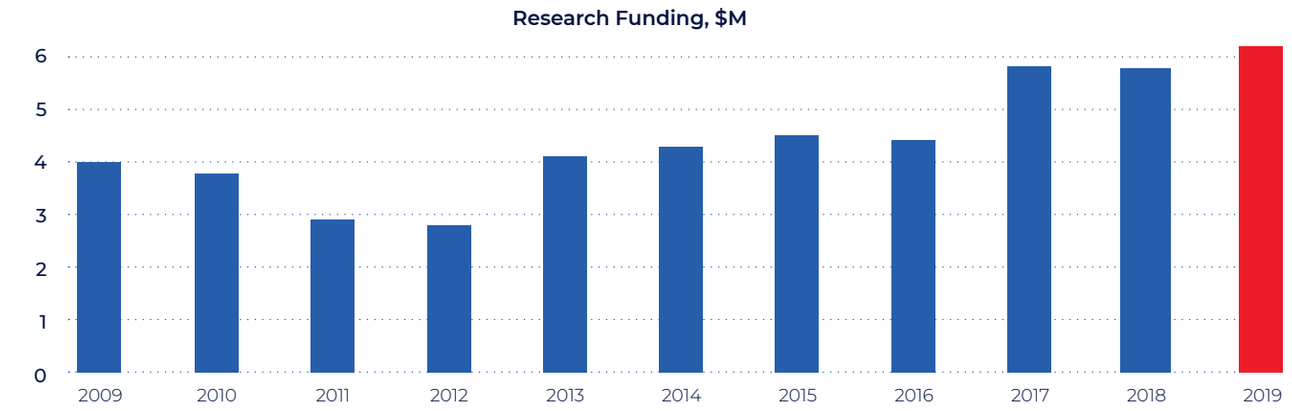
DEVELOPING INTERNATIONAL REPUTATION

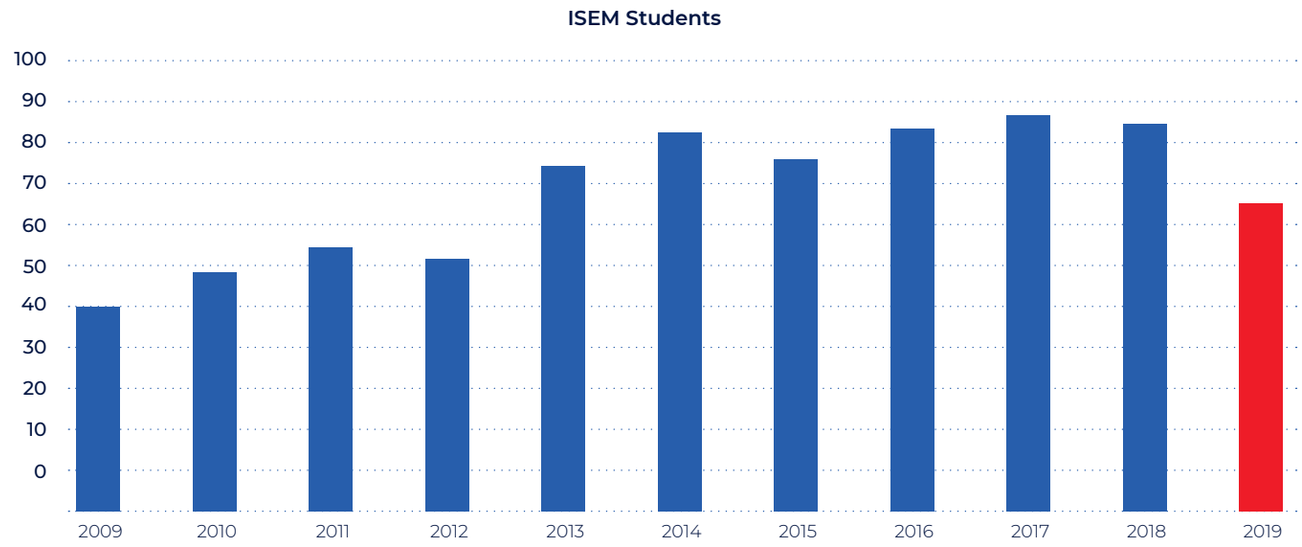


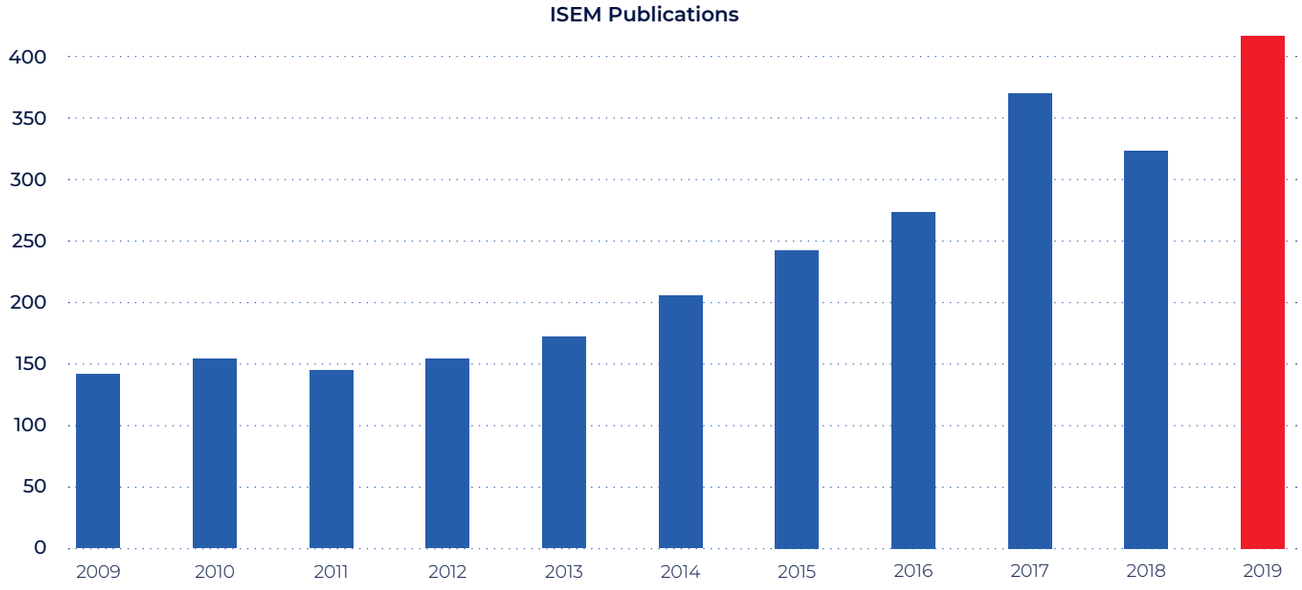
EXPANDING RESEARCH EXCELLENCE

TRANSLATING RESEARCH INTO IMPACT

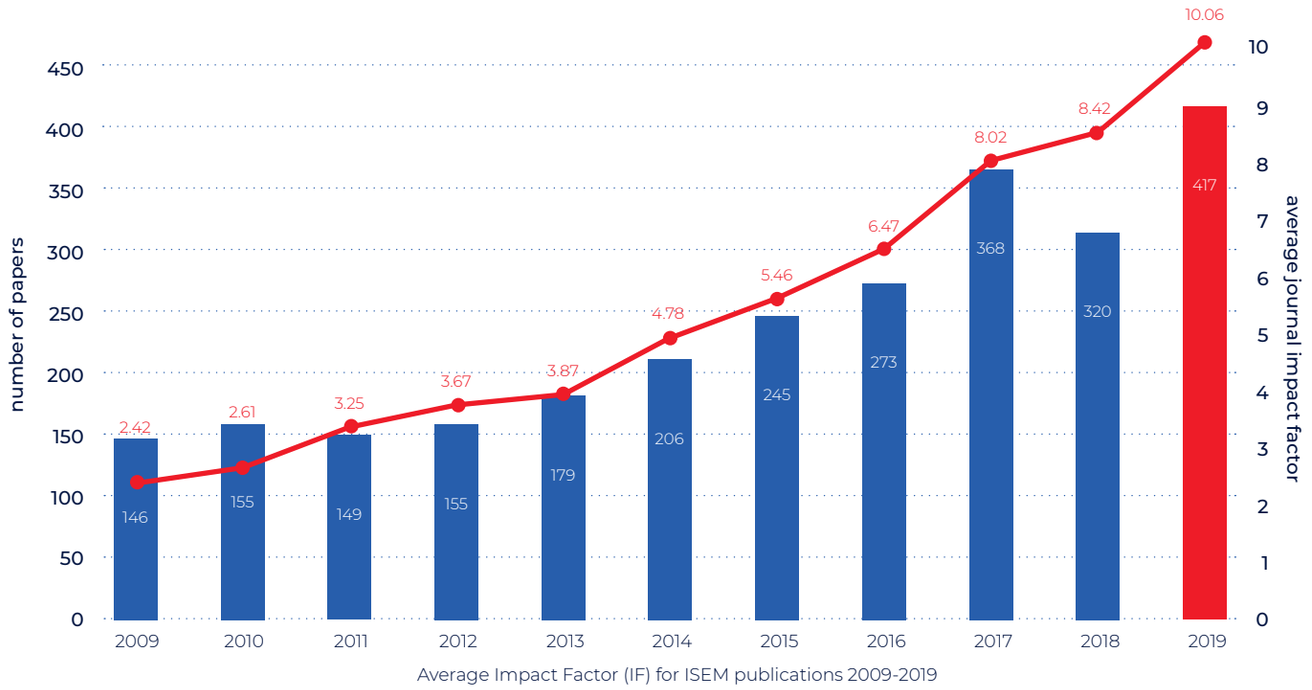
ISEM at a glance





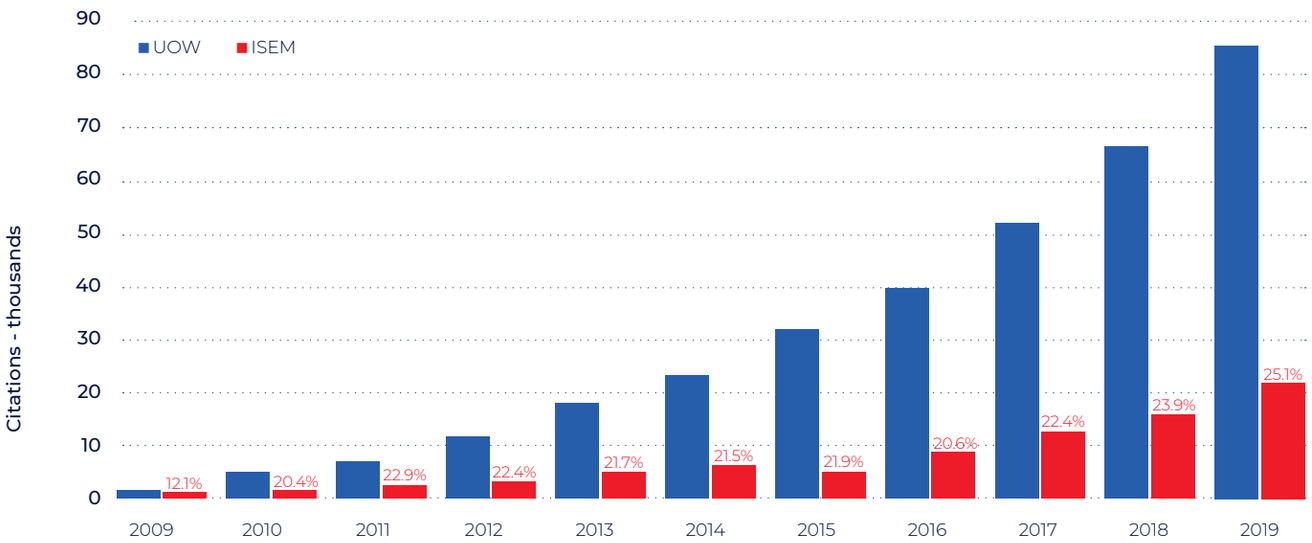


ISEM Publications

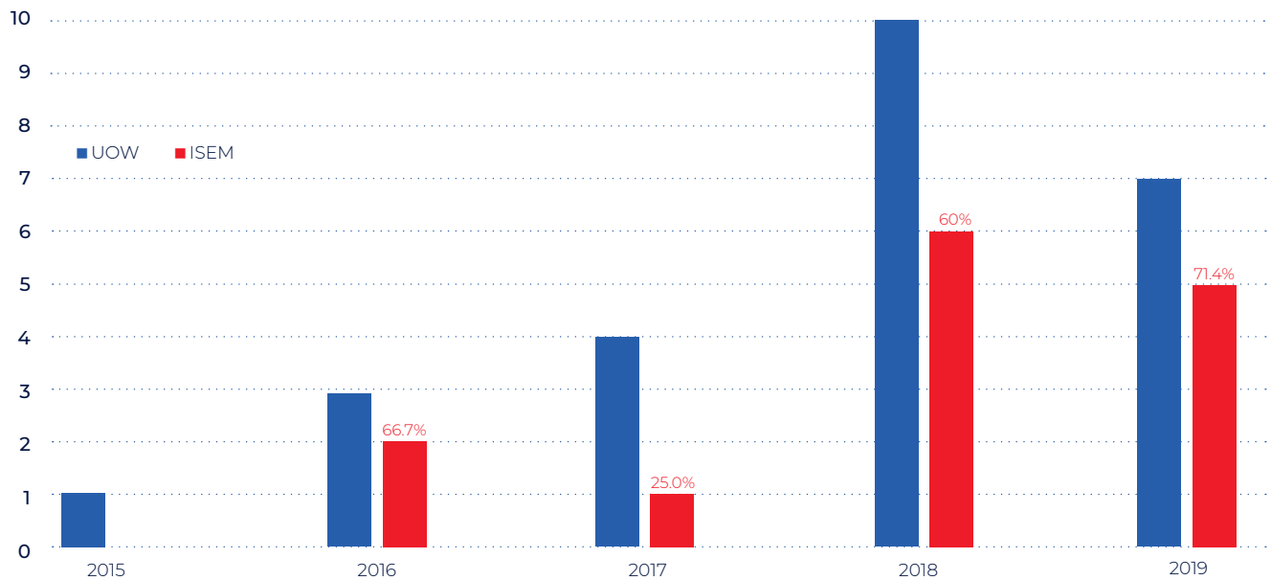


Average Impact Factor (IF) for ISEM publications 2009-2019

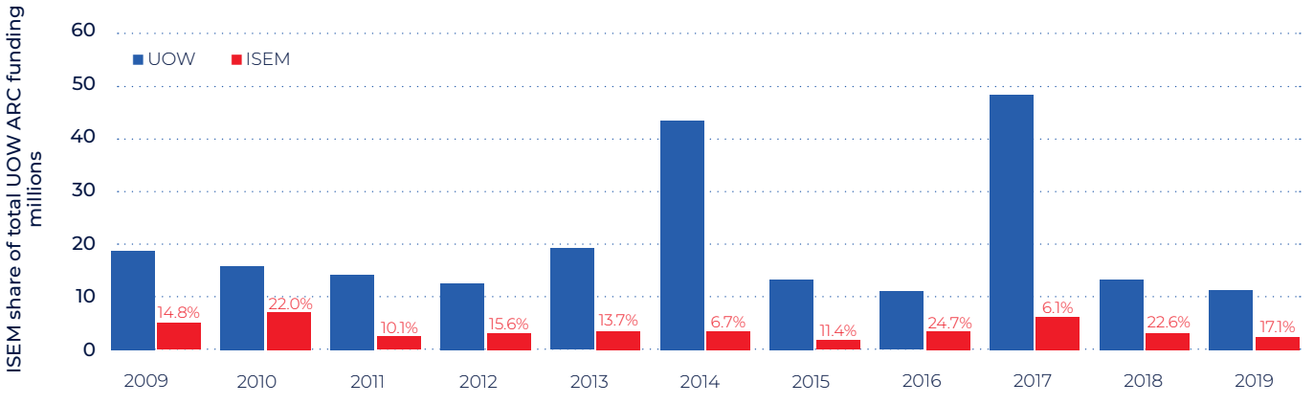
ISEM share of total UOW citations 2009-2019



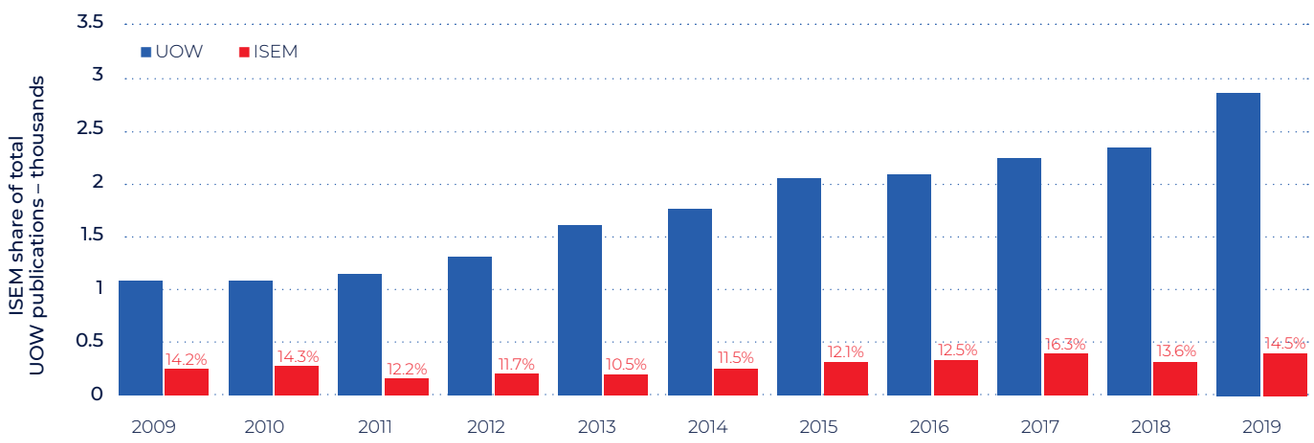
ISEM share of UOW ISI Highly Cited Researchers 2015-2019



ISEM share of total UOW ARC funding 2009-2019



ISEM share of total UOW publications 2009-2019



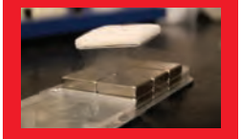
Our Vision

To be leaders in high impact training, research, application, collaborations, gender and diversity equity, and community engagement.

Our Mission

- Identify and foster new research areas and global challenges;
- Expand our research collaborations;
- Produce high output through high impact publications;
- Excellence in HDR student training;
- Promote the translation of scientific developments into technological platforms;
- Promote our reputation in research excellence;
- Improve our operations and governance;
- Promote diversity and gender equity;
- Connect with our local community.

Our Research Programs



SUPERCONDUCTORS AND LOW ENERGY MATERIALS

BATTERY MATERIALS

ENERGY CONVERSION MATERIALS

BATTERY MANAGEMENT SYSTEMS

PIEZOELECTIC AND DIELECTRIC MATERIALS

MULTIFERROIC MATERIALS

THz PHOTONICS AND SOLID STATE PHYSICS

THIN FILM TECHNOLOGY

SCANNING TUNNELING MICROSCOPY

BIOMATERIALS FOR HEALTH

Research programs

SUPERCONDUCTORS AND LOW ENERGY MATERIALS

Developing superconductors and low energy materials for use in electrical and quantum electronic devices such as motors, fault current limiters, transformers and magnetic resonance imaging (MRI) and future low energy quantun spintronic and electronics technologies.

Coordinator: Prof. Xiaolin Wang

BATTERY MATERIALS

Developing advanced materials for fuel cells and solar cells, and advancing rechargeable batteries for electric cars.

Coordinator: Prof. Zaiping Guo

ENERGY CONVERSION MATERIALS

Developing solar cell technology to improve energy generation and help reduce carbon dioxide emissions.

Coordinator: Prof. Jung-Ho Kim

BATTERY MANAGEMENT SYSTEM

Integrated electronic and software system to intelligently manage every single battery cell in a battery pack for the purpose to extend battery life while protecting the cells from any abnormal operations.

Coordinator: Dr. Khay Wai See

PIEZOELECTRIC AND DIELECTRIC MATERIALS

For electromechanical applications including the ultrasound transducers and piezoelectric sensors, and energy related applications such as mechanical energy harvesting and electrostatic energy storage.

Coordinator: Prof. Shujun Zhang

MULTIFERROIC MATERIALS

Focusing on materials with independent/coexisting ferroic properties, such as ferroelectric, magnetic and ferroelastic properties, which have applications in energy storage, harvesting and conversion, information storage and processing.

Coordinator: Prof. Zhenxiang Cheng

THZ PHOTONICS AND SOLID STATE PHYSICS

Developing advanced materials and structures for terahertz science and technology for applications including medicine and biology.

Coordinator: Prof. Chao Zhang

THIN FILM TECHNOLOGY

Innovations and development of thin films structures for applications in superconducting sensing, advanced electronics, and electronic transport.

Coordinator: Prof. Alexey Pan

SCANNING TUNNELLING MICROSCOPY PROGRAM

Our research focuses on nanoscale physical and chemical phenomena with an emphasis on probing the fundamental properties of low-dimensional quantum matters and energy conversion/storage materials. The target is to achieve detailed descriptions of exotic behaviours in low-dimensional materials which form the basis for exploring and utilizing physical and chemical properties associated with surface and interface.

Coordinator: A/Prof. Yi Du

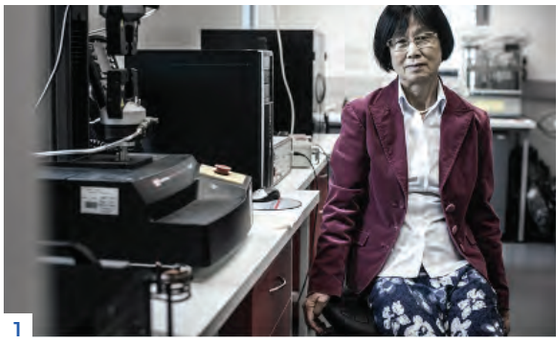
BIOMATERIALS FOR HEALTH

Design, fabrication and study of advanced biocompatible multifunctional materials and composites for various health applications including therapeutic and diagnostic (theranostic) medical applications, melanoma prevention and treatment of oxidative stress.

Coordinator: A/Prof Konstantin Konstantinov

2019 ISEM staff recognition

2019 CLARIVATE ANALYTICS ISI HIGHLY CITED RESEARCHERS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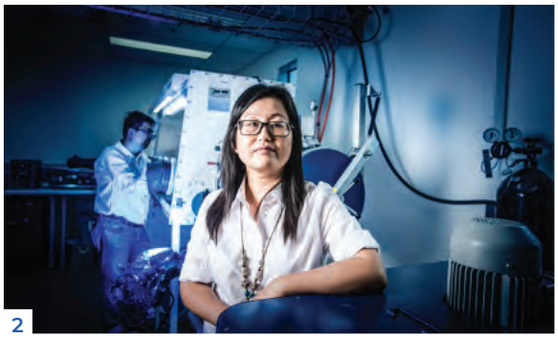
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Figure 1 - Distinguished Professor Hua Kun Liu, Figure 2 - Distinguished Professor Zaiping Guo, Figure 3 - Distinguished Professor Yoshio Bando, Figure 4 - Professor Shulei Chou, Figure 5 - Distinguished Professor Shi Xue Dou

NATIONAL AND INTERNATIONAL RECOGNITION

Professor Shi Xue Dou AM appointed a Member of the Order of Australia

Distinguished Professor Shi Xue Dou AM was appointed a Member of the Order of Australia (AM) for "significant service to science education in the field of superconducting and electronic materials."

Prof Shujun Zhang elected as a Fellow of the American Ceramic Society


6


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Figure 6 – Distinguished Professor Shi Xue Dou Figure 7 - Professor Shujun Zhang

2019 UOW VICE-CHANCELLOR'S AWARDS

25 years service awards

Professor Shi Xue Dou and Associate Professor Josip Horvat received the Vice Chancellor's Award for 25 years of service to UOW.

Vice-Chancellor's Award For Outstanding Achievement In Research Partnership & Impact

Professor Shi Xue Dou and Professor Hua Kun Liu recognised with a Highly Commended citation for their Research Partnership with China BAOWU Steel Group.

Vice-Chancellor's Research Excellence Award For Researcher Of The Year

Distinguished Professor Zaiping Guo was jointly-awarded the 2019 Vice-Chancellor's Research Excellence Award For Researcher Of The Year.

ISEM Governance

MANAGEMENT COMMITTEE

Chairperson:	Prof. Jennifer Martin AC	Deputy Vice Chancellor (Research and Innovation)
	Prof. Xiaolin Wang	Director, ISEM
	Prof. Will Price	Executive Director, AIIM
	Prof. Valerie Linton	Executive Dean, Faculty of Engineering and Information Science, UOW
	A/Prof. Germanas Peleckis	Assistant Director, ISEM; Chair, AIIM Research & Training Committee
	A/Prof. Konstantin Konstantinov	Head of Postgraduate Studies, ISEM

INDUSTRY ADVISORY COMMITTEE

Ms. S. Moroz	CEO, Nano Nouvelle Ltd
Mr. B. Lynch	CEO, Valley Longwall International Pty. Ltd, Newcastle, Australia
Mr. M. Sahari	CEO, Malaysian Automotive Institute, Malaysia
Mr. R. Huang	President, Australian Innovative Industry Park, Australia
Mr. J. Grimes	CEO, Australian Energy Storage Council, Australia
Mr. Y. C. Li	President, Hong Cheng Electric Power Co Ltd, Anshan, P. R. China
Mr. T. Lee	President, McNair Industrial Estate Ltd, P. R. China
Mr. H. Bustamante	Principal Scientist Treatment, Sydney Water, Australia
Mr. M. Li	General Manager, Hebei ANZ New Energy Technology Co Ltd, China
Mr. J. Wu	Chairman of the Board, DLG Battery Co Ltd, Shanghai, P. R. China
Mr. M. Tomsic	Managing Director, Hyper Tech Research Ltd, Ohio, USA
Dr. X. F. Gao	General Manager, DLG Co Ltd, Shenzhen, P. R. China
Mr. C.H. Yao	Institute of Tianjin Benefo, P. R. China
Mr. A. Kittel	Managing Director, Redarc Electronics, Adelaide, SA, Australia
Mr. J. Brown	Managing Director, Charge Point Australia NSW, Australia
Dr. Y. Sharma	Chief Technological Officer, Galaxy Resources Ltd
Mr. J. Y. Xu	Chief Executive Officer, Ningbo Jain Sen Mechanism Ltd
Mr. C. Fu	Chief Executive Officer, Zhuo Yi Technology Ltd, Yingko, China
Mr. R. Tandiono	Chief Executive Officer, PT Nipress Tbk, Indonesia
Dr. Ho-Yong Lee	President, Ceracomp Inc., Korea
Mr. R. Cameron	Managing Director, NPG Mining

ADVISORY COMMITTEE

Prof. J. H. Li	Vice President, Chinese Academy of Sciences
Prof. P. X. Zhang	Chinese Academician, President, Bao Steel Research Institute
Prof. M. Fuhrer	Director, ARC Center of Excellence in Future Low Energy Electronics Technology, ARC Laureate Fellow, Monash University
Prof. A. Hamilton	Executive Director, ARC Center of Excellence in Future Low Eenergy Electronics Technology
Prof. K. Kalantar-Zadeh	Director, ARC Laureate Fellow, University of New South Wales
Prof. R. Taylor	Adjunct Professor, Queensland University of Technology, Australia
Prof. P. Robinson	Chair, Cast CRC Ltd

Personnel

DIRECTOR

Distinguished Prof. Xiaolin Wang (BSc, MSc, PhD)

ASSISTANT DIRECTOR

A/Prof. Germanas Peleckis (BCh, MSc, PhD)

HEAD OF POSTGRADUATE STUDIES

A/Prof. Konstantin Konstantinov (PhD)

ARC FELLOWS

Distinguished Prof. Zaiping Guo (ARC FT-3 Fellow)
Prof. Shujun Zhang (ARC FT-2 Fellow)
A/Prof. Yi Du (ARC FT-2 Fellow)
Dr. Wei Kong Pang (ARC FT-1 Fellow)
Dr. David Cortie (ARC DECRA Fellow)
Dr. Wei Jie Li (ARC DECRA Fellow)
Dr. Zhi Li (ARC DECRA Fellow)
Dr. Ji Liang (ARC DECRA Fellow)
Dr. Yan Lu (ARC DECRA Fellow)
Dr. Wenping Sun (ARC DECRA Fellow)
Dr. Yunxiao Wang (ARC DECRA Fellow)
Dr. Chao Wu (ARC DECRA Fellow)
Dr. Guanglin Xia (ARC DECRA Fellow)
Dr. Tengfei Zhou (ARC DECRA Fellow)

ISEM STAFF

Distinguished Prof. Shi Xue Dou
Distinguished Prof. Hua Kun Liu
Distinguished Prof. Yoshio Bando
Prof. Jiazhao Wang
Prof. Zhenxiang Cheng
Prof. Jung Ho Kim
A/Prof. Shulei Chou
Dr. Xun Xu (Senior Research Fellow)
Dr. Khay Wai See (Senior Research Fellow)
Dr. Si Zhou (Vice Chancellor's Research Fellow)
Dr. Haifeng Feng (Research Fellow)
Dr. Chao Han (Research Fellow)
Dr. Jon Knott (Research Fellow)
Dr. Kai Chin Lim (Research Fellow)
Dr. Weihong Lai (Research Fellow)
Dr. Wenbin Luo (Research Fellow)
Dr. Xiao Lu (Research Fellow)
Dr. Jianfeng Mao (Research Fellow)
Dr. Long Ren (Research Fellow)
Dr. Jianli Wang (Research Fellow)
Dr. Zheyin Yu (Research Fellow)
Dr. Christophe Didier (Joint UOW-ANSTO Associate Research Fellow)
Dr. Jeonghun Kim (Associate Research Fellow)
Dr. Peng Liu (Associate Research Fellow, ARC COE in FLEET Fellow)
Dr. Qiannan Liu (Associate Research Fellow)
Dr. Zengji Yue (Associate Research Fellow, ARC COE in FLEET Fellow)
Dr. Frank Fei Yun (Associate Research Fellow, ARC COE in FLEET Fellow)
Dr. Neng Zhang (Associate Research Fellow)

ISEM AND EIS JOINT STAFF

Prof. Roger Lewis (Associate Dean, Faculty of EIS)
Prof. Chao Zhang (Senior Professor, Faculty of EIS)
Prof. Alexey Pan (Professor, Faculty of EIS)
Prof. Zaiping Guo (Distinguished Professor, Faculty of EIS)
A/Prof. Rodney Vickers (Associate Professor, Faculty of EIS)
A/Prof. Yue Zhao (Associate Professor, Faculty of EIS)
A/ Prof. Josip Horvat (Associate Professor, Faculty of EIS)
Dr. Enbang Li (Senior Lecturer, Faculty of EIS)
Dr. Carey Freeth (Senior Lecturer, Faculty of EIS)

ISEM SUPPORT STAFF

Dr. Tania Silver (Technical Editor)
Dr. Dongqi Shi (Senior Instrument Scientist)
Mrs. Crystal Mahfouz (Administrative Officer)

HONORARY FELLOWS

Prof. Edward Collings, Ohio State University
Prof. Lei Jiang (Honorary Professorial Fellow), Chinese Academy of Science, Institute of Chemistry
Prof. Tom Johansen (Honorary Professorial Fellow), Oslo University
Prof. Zhong Fan Liu (Honorary Professorial Fellow), Peking University, Fellow of CAS
Prof. Kostya Ostrikov (Honorary Professorial Fellow), ARC Future Fellow, CSIRO
Dr. Vanessa Patterson, Principal Scientist, ANSTO
Prof. Chang Ming Li (Honorary Professorial Fellow), Royal Society of Chemistry, Southwest Univ.
Dr. Zhen Li (Senior Research Fellow)
Dr. Scott Needham, Xinova LLC
Prof. Guoxiu Wang, Future Fellow, Univ. of Technology, Sydney
Prof. Dongyuan Zhao (Honorary Professorial Fellow), Fellow of CAS, Fudan University
Prof. Yi Xie (Honorary Professorial Fellow), University of Sci & Tech China, Hefei
Prof. Liming Dai (Honorary Professorial Fellow), UOW VISA Fellow, Case Western Reserve University
Prof. Wei Huang (Honorary Professorial Fellow), North-Western University of Technology
Dr. Md Shariar Hossain (Honorary Fellow) Senior Lecturer, The University of Queensland Australia

Our Major Initiatives

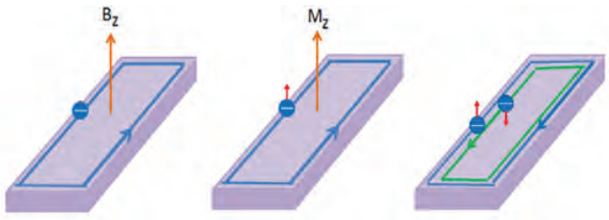
NODE: ARC CENTRE OF EXCELLENCE IN FUTURE LOW-ENERGY ELECTRONICS TECHNOLOGIES

The ARC Centre of Excellence in Future Low-Energy Electronics Technologies (FLEET) addresses a grand challenge: reducing the energy used in information and communication technology (ICT), which now accounts for 8% of the electricity use on Earth, and is doubling every 10 years. The current, silicon-based technology is 40 years old, and reaching the limits of its efficiency. To allow computing to continue to grow, we need a new generation of ultralow energy electronics. FLEET is pursuing the three approaches to develop systems in which electrical current can flow with near-zero resistance:

Topological materials

Exciton superfluids

Light-transformed materials



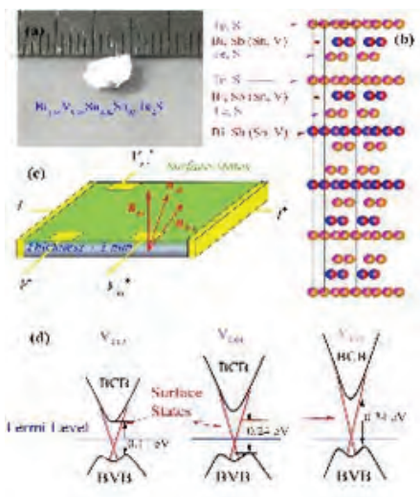
ISEM hosts the University of Wollongong node of FLEET under the leadership of ISEM Director, Professor Xiaolin Wang. Prof. Wang is also a theme leader of FLEET's efforts in developing the novel topological materials - a new class of materials - and 2D materials that will underpin a new generation of ultra-low energy electronics. At ISEM, Prof. Wang's team studies the electronic, spintronic, and superconducting properties of novel electronic and spintronic systems such as topological insulators, high spin polarised materials, spin gapless semicondutors, superconductors, multi-ferroic materials, and new energy materials in various forms such as single crystals, atomically thin (2D) and thin films, and nano-devices.

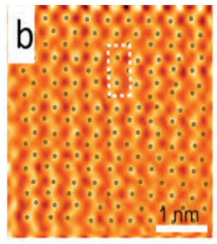
FLEET NODE 2019 HIGHLIGHTS

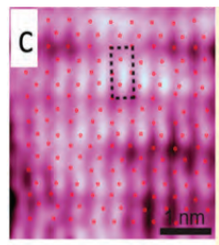
Significant scientific breakthroughs were made at the ISEM FLEET node in 2019, including:

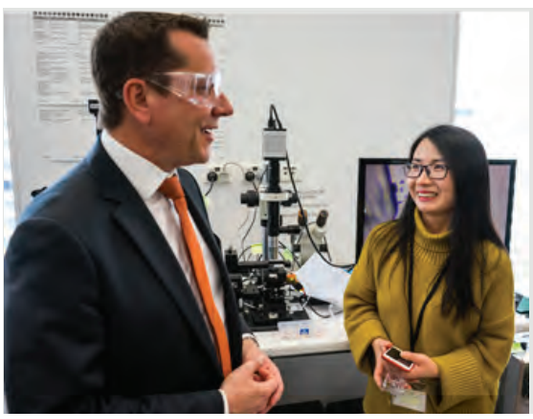
- Discovering 3D topological insulator crystals with bandgap much greater than room temperature and robust topological surface states up to 50 degrees Kelvin
- Observing possible excitonic insulating state on antimony (Sb) nanoflakes
- Fine-tuning the topological insulator antimony telluride (Sb_2Te_3) by doping with iron

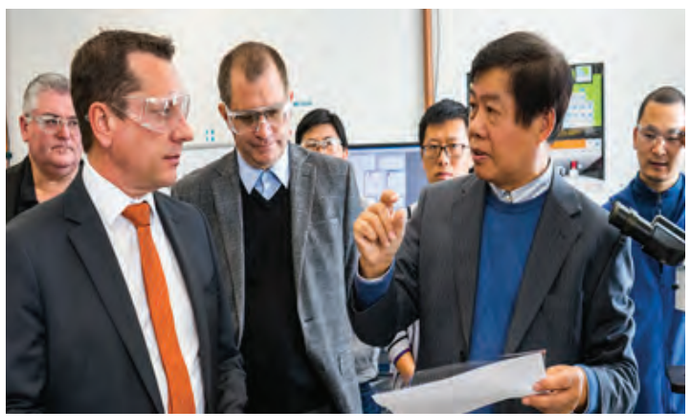
The ISEM FLEET node also hosted Mr Paul Scully MP, Member of the NSW Legislative Assembly (Member for Wollongong) in 2019.











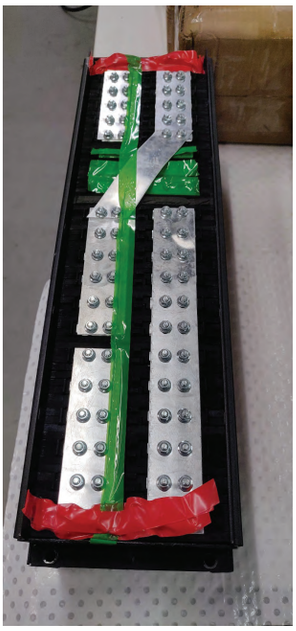
THE SMART SODIUM STORAGE SYSTEM (S⁴) PROJECT

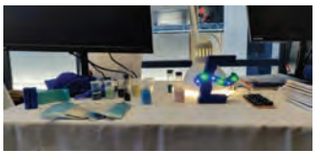
The Smart Sodium Storage System (S⁴) Project is a $10.6M project which aims to develop and demonstrate novel sodium-ion battery technologies for use in renewable energy storage applications. The S⁴ Project is funded in part by the Australian Renewable Energy Agency (ARENA), and is being led by the University of Wollongong. Our Consortium Partners include Liao Ning Hong Cheng Electric Power Co., Hebei ANZ New Energy Technology Co., and Sydney Water.

The core focus of the S⁴ Project is to translate research successes in developing novel sodium-ion battery materials at the ISEM into commercial-ready batteries. Projct activities have centred on scaling production of materials and sodium-ion battery cells in partnership with our Industry Partners, leveraging their expertise in large-sclae development and manufacturing.

We'll be demonstrating these innovative sodium-ion batteries at the Illawarra Flame House in Wollongong, and the Bondi Sewage Pumping Station - located just behind Sydney's iconic Bondi Beach.

The S⁴ Project commenced in early 2016 and will conclude in 2020.





S⁴ PROJECT 2019 HIGHLIGHTS

Significant scientific and manufacturing breakthroughs were made in the S⁴ Project in 2019, including:

- Publication of 22 scholarly works, including two PhD theses supported by the project
- Scaling of battery manufacturing facilities at Industry Partner sites
- Delivery of first S⁴ Project "mass produced" sodium-ion battery cells to UOW for testing
- Development of 'residential testbed' for deploying and demonstrating the S⁴ Project sodium-ion batteries at the Illawarra Flame house, located adjacent to the ISEM research facilities

The S⁴ Project team also took part in a number of knowledge sharing activities in 2019, including presenting at several international conferences, the Sydney Water Science Week event, and in the ISLE Utilities Technology Roadshow.

S⁴ PROJECT CONSORTIUM PARTNERS

Australian Government Australian Renewable Energy Agency ARENA

UNIVERSITY OF WOLLONGONG AUSTRALIA

ANZ

宏成电力 HONGCHENG ELECTRIC POWER

Sydney WATER

2019 ISEM student awards

EXCELLENCE AWARD

The Student Excellence Award acknowledges outstanding academic performance, highest level of dedication towards work culture, laboratory and equipment maintenance, extra-curricular career development, and general perception of the peers.

The excellence award winners:
Gemeng Liang, Wanlin Wang, Zhijie Wang, Weiyao Zhao


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Figure 8 - Gemeng Liang, Figure 9 - Wanlin Wang, Figure 10 - Zhijie Wang, Figure 11 - Weiyao Zhao

STUDENT BEST PAPER AWARD

The Student Best Paper Award acknowledges an original work published in scientific journals of the highest academic standing and reputation. To be eligible for the award, publication must have appeared in printed form in 2019 and the nominee must be either 1st or corresponding author:

The best paper award winners:
Sailin Liu, Zichao Yan, Letao Yang

Sailin Liu, et al., "An intrinsically non-flammable electrolyte for high performance potassium batteries", Angewandte Chemie International Edition 59, 3638 (2019).

Zichao Yan et al., "Nickel sulfide nanocrystals on nitrogen-doped porous carbon nanotubes with high-efficiency electrocatalysis for room-temperature sodium-sulfur batteries", Nature Communications 10, 4793 (2019).

Letao Yang et al., "Perovskite lead-free dielectrics for energy storage applications", Progress in Materials Science 102, 72 (2019).


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Figure 12 - Sailin Liu, Figure 13 - Zichao Yan, Figure 14 - Letao Yang

STUDENT MERIT AWARD

The Student Merit Award acknowledges excellent academic performance, active participation in day-to-day life of the institute, and shows great potential to excel even further in the near future.

The merit award winners:
Al Jumlat Ahmed, Peng Li, Mohanad Mohammad, Alain Moriana, Yanhua Sun, Zhibin Wu, Xiaobo Zheng


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Figure 15 - Al Jumlat Ahmed, Figure 16 - Peng Li, Figure 17 - Mohanad Mohammad, Figure 18 - Alain Moriana, Figure 19 - Yanhua Sun, Figure 20 - Zhibin Wu, Figure 21 - Xiaobo Zheng

Current and Ongoing Research Projects

ARC CENTRE OF EXCELLENCE

ARC Centre of Excellence in Future Low Energy Electronics Technologies

Years Funded:	2017	2018	2019	2020	2021	2022	2023
	$224,105	$216,211	$218,842	$218,842	$218,842	$221,474	$221,474

Total Funding: $1,539,788

Project ID: CE170100039

Lead CI: M. Fuhrer (University of Melbourne)

UOW CI: X. L. Wang

Project Summary: This Centre aims to develop the scientific foundation and intellectual property for new electronics technologies. Decreasing energy use is a major societal challenge, and this Centre aims to meet that challenge by realising fundamentally new types of electronic conduction without resistance in solid-state systems at room temperature. Novel resistance-free electronic phenomena at room temperature are expected to form the basis of integrated electronics technology with ultra-low energy consumption. This Centre's development of innovative electronics could put Australia at the forefront of the international electronics industry.

ARC DISCOVERY PROJECTS

Multifunctional 2D materials for sustainable energy applications

Years Funded:	2016	2017	2018	2019
	$152,000	$152,000	$152,000	$154,000

Total Funding: $610,000

Project ID: DP160102627

Chief Investigators: S. X. Dou, Z. Q. Sun, X. Xu, T. Liao

Partner Investigator: Z. F. Liu, H. Zhang, J.-B. Baek, L. M. Dai

Project Summary: This project seeks to explore the great potential of novel graphene-like two dimensional (2-D) materials for energy applications. 2-D materials, which possess atomic or molecular thickness and infinite planar lengths, are regarded as a building block for many applications due to their unique nanostructures, electronic and mechanical properties. This project is focused on the design and exploration of layered two-dimensional artificial graphene and graphene analogues with 'on-demand' properties to exploit advanced energy applications. There is now a pressing need to integrate graphene sheets into multidimensional and multifunctional systems with spatially well-defined configurations, and integrated systems with a controllable structure and predictable performance. Project outcomes may lead to next-generation devices in energy storage and other applications.

Liquid phase hydrogen carriers for energy storage and delivery

Years Funded:	2017 $131,000	2018 $130,000	2019 $130,000
Total Funding:	$391,000		
Project ID:	DP170101773		
Chief Investigators:	Z. G. Huang, H. K. Liu		
Partner Investigator:	H. B. Yu, X. B. Yu		
Project Summary:	This project aims to overcome hydrogen storage and delivery issues by developing liquid-phase hydrogen storage materials with high hydrogen capacity, exceptional stability and that do not change phase during hydrogen evolution. This project will build on the recent synthesis of strategically important hydrogen storage compounds. The innovative liquid-phase hydrogen storage and delivery technology will enable effective usage of established liquid fuel distribution techniques and infrastructure throughout the country. The project would benefit renewable energy, chemical, and manufacturing industries, where new employment opportunities would be created.		

Atomically thin superconductors

Years Funded:	2017 $124,500	2018 $124,000	2019 $124,000
Total Funding:	$372,500		
Project ID:	DP170104116		
Chief Investigators:	Z. Li, Z. X. Cheng		
Partner Investigator:	Q. K. Xue		
Project Summary:	This project aims to explore two-dimensional superconducting materials and elucidate the origins of their superconductivity. High temperature superconductivity in single layer iron-based superconductors offers a platform for exploring superconductors with even higher critical temperature (Tc) and has aroused great hope of understanding the underlying mechanisms for high Tc superconductivity. This project is expected to introduce physics and materials, leading to a better understanding of the two-dimensional superconducting phenomenon and the discovery of physical phenomena for new electronic devices.		

Two-dimensional plasmonic heterogeneous nanostructures for photocatalysis

Years Funded:	2017 $171,000	2018 $171,000	2019 $171,000
Total Funding:	$513,000		
Project ID:	DP170101467		
Chief Investigators:	S. X. Dou, Y. Du, X. Xu, G. Peleckis		
Partner Investigator:	J. H. Ye, W. C. Hao, L. Chen		
Project Summary:	This project aims to design and explore two-dimensional heterogeneous photocatalysts that can convert solar energy into usable chemical energy. This project will investigate the correlation between surface plasmonic resonance and photocatalytic activities on the atomic level. Heterogeneous engineering and in-situ investigation of atomic-level photocatalytic dynamics is expected to yield several new full-solar-spectrum photocatalysts. The project is expected to contribute to the understanding of the processes and mechanisms underlying photocatalysis, and lead to useable, stable and durable photocatalytics. The outcomes will enable efficient, cost-effective and reliable production of clean energy in a low-emission way.		

Potassium ion batteries for large scale renewable energy storage

Years Funded:	2017	2018	2019
	$165,500	$164,000	$164,000
Total Funding:	$493,500		
Project ID:	DP170102406		
Chief Investigators:	Z. P. Guo, K. Konstantinov		
Partner Investigator:	X. W. Lou, Z. Zhou		
Project Summary:	The project aims to develop potassium ion batteries for renewable energy storage and conversion. Potassium ion batteries could be the most promising choice for large-scale electrical energy storage, particularly for renewable energy sources and smart electrical grids, due to their low cost, natural abundance and the advantages of potassium compared to lithium/sodium ion batteries. This study will research the electrochemical reactions and charge transfer pathway of electrode materials with excellent potassium ion storage performance. This project is expected to develop high performance potassium ion batteries and advance the prominence of Australia in the global renewable energy market.		

Development of ambient air operation rechargeable sodium-air batteries

Years Funded:	2018	2019	2020
	$124,388	$124,000	$124,000
Total Funding:	$372,388		
Project ID:	DP180101453		
Chief Investigators:	J. Z. Wang, K. Konstantinov		
Partner Investigator:	W. S. Yang, Q. F. Gu		
Project Summary:	This project aims to develop Sodium (Na)-air batteries for large-scale renewable energy storage. The expected outcomes include development of new air cathode materials, gel polymer electrolytes and oxygen selective membranes, establishing novel Na-air battery systems for ambient air operation using advanced electrode materials, gel polymer electrolytes, and oxygen selective membranes, and exploring the electrochemical reaction mechanisms and degradation Na-air battery systems by the operando study method and other advanced techniques. The success of this project will contribute to the Australia Science and Research Priority area of energy.		

Magnetic skyrmion materials for next generation spintronic-based devices

Years Funded:	2019	2020	2021
	$137,000	$137,000	$136,000
Total Funding:	$410,000		
Project ID:	DP190100150		
Chief Investigators:	Z. X. Cheng, X. L. Wang		
Partner Investigator:	W. H. Wang, H. X. Yang, E. Gilbert		
Project Summary:	Magnetic skyrmions are a novel class of materials with unique spin arrangement, making them suitable for the next generation of information processing and storage with ultrahigh density and extremely low energy consumption. This project aims to establish Australia as a world authority in the field of magnetic skyrmions and their applications, by developing ground-breaking materials and advanced technologies. The expected outcomes of this project include the creation of new functional materials, leading to a better understanding of the skyrmions and producing a foundation for the future development of novel information storage devices.		

FUTURE FELLOWSHIPS

Exploration of advanced nanostructures for sodium-ion battery application

Years Funded:	2015	2016	2017	2018	2019
	$117,000	$222,000	$222,000	$222,000	$117,000
Total Funding:	$900,000				
Project ID:	FT150100109				
Chief Investigator:	Z. P. Guo				
Project Summary:	The aim of this project is to develop advanced nanostructured electrode materials for high energy, long service life sodium ion batteries. Sodium-ion batteries are the most promising choice for large-scale electrical energy storage, in particular for renewable energy sources and smart electric grids, owing to their low cost and natural abundance of sodium. The success of this project will advance fundamental understanding of sodium-ion batteries, and provide techniques for the development of a promising low-cost system for renewable energy storage, which is urgently needed in smart electricity grids.				

High-voltage electrode materials for lithium-ion batteries

Years Funded:	2016	2017	2018	2019	2020
	$82,000	$163,000	$163,000	$163,000	$82,000
Total Funding:	$653,000				
Project ID:	FT160100251				
Chief Investigator:	W. K. Pang				
Project Summary:	This project aims to establish a complete battery research system and develop high-voltage electrode materials for lithium-ion batteries through mechanistic understanding obtained in operando studies. Lithium-ion batteries are the most promising choice for portable electronic devices, including electric vehicles, due to their high power and energy performance compared with other battery technologies. The success of this project is expected to advance fundamental understanding of lithium-ion batteries, and provide techniques to develop a promising high-energy and high-power battery system.				

Functional two-dimensional materials for photocatalysis

Years Funded:	2018	2019	2020	2021	2022
	$110,500	$219,000	$219,000	$219,000	$110,500
Total Funding:	$878,000				
Project ID:	FT180100585				
Chief Investigator:	Y. Du				
Project Summary:	This project aims to explore and tailor two-dimensional materials and heterostructures by new synthetic strategies, and to develop a comprehensive understanding of the effects of crystalline and electronic structures on photocatalysis at the atomic level. The project expects to provide deep insight into catalytic mechanisms by bridging the current gap between realistic systems and theoretical calculations. By simply using solar energy, the project aims to provide an efficient and durable method for clean energy generation/conversion, and carbon sequestration. This project will build national research capacity in an emerging field and put Australia at the forefront of research on photocatalysis to address energy and environmental issues.				

DECRA FELLOWSHIPS

Nanostructured metal hydrides for practical hydrogen storage applications

Years Funded:	2017 $120,000	2018 $120,000	2019 $120,000
Total Funding:	$360,000		
Project ID:	DE170100362		
Chief Investigators:	G. L. Xia		
Project Summary:	This project aims to synthesise nanostructured metal hydrides with particle size smaller than 5 nm. The practical applications of metal hydrides as advanced solid-state hydrogen storage materials require substantial knowledge and delicate engineering of materials on the nanoscale. Combined with controllable modification on the nanoscale, the optimised metal hydrides will enhance the performance of hydrogen storage materials. This project is expected to advance understanding of the technologies of metal hydrides as hydrogen storage materials and develop practical applications of metal hydrides in storage tanks for fuel cells. Hydrogen energy could also reduce carbon dioxide emissions and alleviate air pollution.		

Carbon-based catalysts for polysulphide redox reactions in lithium-silicon batteries

Years Funded:	2017 $120,000	2018 $120,000	2019 $120,000
Total Funding:	$360,000		
Project ID:	DE170100871		
Chief Investigators:	J. Liang		
Project Summary:	This project aims to develop surface-engineered carbons as multifunctional catalysts to accelerate the polysulphide redox reactions for lithium-silicon batteries. High capacity storage of electricity is the key to efficient use of renewable and clean energy resources and the development of emission-free technologies. This project will provide high-performance lithium-silicon batteries with high energy density, high efficiency, and long life. Its success is expected to contribute to energy technologies, reduce the dependence of household and industrial energy consumption on fossil fuels, enhance Australia's long-term viability, and bring economic, environmental, and social benefits to the nation.		

Room-temperature sodium-sulphur batteries

Years Funded:	2017 $120,000	2018 $120,000	2019 $120,000
Total Funding:	$360,000		
Project ID:	DE170100928		
Chief Investigators:	Y. X. Wang		
Project Summary:	This project aims to develop silicon-based cathode materials for high-performance RT-sodium/sulphur batteries. These are expected to improve the sulphur electroactivity with sodium and supress the shuttle effect, achieving high energy density and cycling stability. This project will accelerate the sluggish electrochemical reactions between sulphur and sodium by embedding sulphur in hollow mesoporous carbon nanospheres, and modify the surface of the mesoporous carbon nanospheres' host. A superior RT-sodium/sulphur battery with high energy density, a long cycling life, and stationary storage has potential to shift fossil fuels towards renewable energy system to power the economy in the long run.		

Electrode materials for sodium storage

Years Funded:	2017 $120,000	2018 $120,000	2019 $120,000
Total Funding:	$360,000		
Project ID:	DE170101426		
Chief Investigators:	C. Wu		
Project Summary:	This project aims to develop phosphide-based electrode materials for high-performance sodium-ion batteries (SIBs) with high reversible capacity, superior rate capability and long cycle life. SIBs have great advantages in terms of low cost and infinite sodium resources, but the large size of the sodium-ion creates kinetic problems and a significant volume change for electrode materials. This project aims to design and synthesise phosphide-carbon hybrids with multi-scale, multi-dimension and hierarchical architectures as electrodes to overcome these problems. Expected outcomes include understanding the sodium-storage mechanisms, the size effect, and the architecture role for phosphide-based electrodes.		

Engineering magnetism at the atomic scale in topological insulators

Years Funded:	2018 $118,000	2019 $118,000	2020 $118,000
Total Funding:	$354,000		
Project ID:	DE180100314		
Chief Investigators:	D. Cortie		
Project Summary:	This project aims to explore strategies to optimise the magnetisation and Curie temperature by incorporating dopants via ion implantation, and exploiting proximity effects in heterostructures with magnetic thin films. The recently discovered magnetism in topological insulators opens up a new class of materials with potential applications in energy-efficient electronics, data storage and information processing. The central challenges are to control the underlying magnetic structure and stabilise magnetic order at desirable temperatures. The project expects to discover new composite materials and advance our knowledge for designing magnetic components in the next generation of electronics with ultra-low power dissipation.		

High performance lead-free piezoelectrics based on polar nanoregions

Years Funded:	2018 $120,000	2019 $120,000	2020 $120,000
Total Funding:	$360,000		
Project ID:	DE180101454		
Chief Investigators:	F. Li		
Project Summary:	This project aims to enhance the electro-mechanical couplings of lead free piezoelectrics via introducing polar nanoregions for medical transducers applications. This is expected to impact on the design and development of high-performance lead free piezoelectrics, and have environmental benefits through replacing lead based counterparts.		

Long life sodium ion batteries by optimising initial coulombic efficiency

Years Funded:	2018 $118,000	2019 $118,000	2020 $118,000
Total Funding:	$354,000		
Project ID:	DE180101478		
Chief Investigators:	W. J. Li		
Project Summary:	The project aims to develop novel structured phosphorus (Sn/P)-based composites as anode electrodes for sodium ion storage, which have high initial coulombic efficiency (charge capacity), high capacity and stable cycle life. Approaches of modifying surface structure will improve initial coulombic efficiency of Sn/P-based composites, and strategies to stabilise solid electrolyte interphase (SEI) film will obtain long-cycle stability. The success of this project will greatly accelerate the commercialisation of sodium ion batteries and support the utilisation of renewable energy in Australia.		

Interphases and interfaces of nanomaterials in potassium-ion batteries

Years Funded:	2019 $128,000	2020 $128,000	2021 $128,000
Total Funding:	$384,000		
Project ID:	DE190100504		
Chief Investigators:	T. F. Zhou		
Project Summary:	This project aims to improve the fundamental understanding of interfacial interactions in multicomponent materials, which is a critical precursor to successfully designing and experimentally validating novel layered sulphide systems for potassium-ion batteries. A new layered structure construction technique will be employed to enhance the intrinsic electronic and ionic conductivities in the anode by controllable interphase and interface engineering. The expected outcomes of this project are to generate potassiumion batteries with high energy density, high safety, and long cycle life for next generation energy storage. This project should give Australia a competitive edge in the globally emerging sustainable manufacturing and energy-storage technologies.		

Engineering of exotic electronic properties in atomically thin antimony

Years Funded:	2019 $120,000	2020 $120,000	2021 $120,000
Total Funding:	$360,000		
Project ID:	DE190100219		
Chief Investigators:	Z. Li		
Project Summary:	This project aims to introduce a new method of engineering electronic resistance properties of materials to reduce energy consumption in computation. Next-generation electronic devices require materials hosting current at near-zero resistance to reduce energy consumption and heat dissipation in computation. Using a novel air-stable topological material, the project will use band engineering techniques to enable the production of near-zero resistance electronic material. This project will advance the knowledge required for exploring and designing materials with novel electronic properties. The advanced materials engineering techniques and exotic phase of matter identified in this project will support the development of next-generation electronic device technologies.		

Nanostructures derived from metal-organic frameworks for sodium-ion batteries

Years Funded:	2019 $136,000	2020 $136,000	2021 $136,000
Total Funding:	$408,000		
Project ID:	DE190100082		
Chief Investigators:	Y. Lu		
Project Summary:	This project aims to overcome poor reaction kinetics and the lack of effective anode materials owing to the large size of sodium-ions in high performance sodium-ion batteries. The project will explore a series of functional nanomaterials with unique nanostructures and complex compositions, enabled by metal-organic framework assisted synthetic methods. High performance sodium ion batteries are demonstrating great potential to meet the future demand for large-scale and low-cost stationary energy storage. However, their practical implementation is still hindered by their poor reaction kinetics and the lack of effective anode materials owing to the large size of sodium-ions. The project outcomes will promote the commercialisation of sodium ion batteries and power Australia's sustainable economy in the long run.		

ARC LINKAGE PROJECTS

Development of the next generation battery storage system for smart grid

Years Funded:	2016 $90,000	2017 $90,000	2018 $90,000	2019 $90,000
Industry Fund:		$100,000	$100,000	$50,000
Total Funding:	$610,000			
Project ID:	LP160100273			
Chief Investigators:	S. X. Dou, W. P. Sun, K. W. See, X. Xu			
Industry Partner:	Tianjin Benefo Machinery Equipment Group Central Research Institute			
Project Summary:	This project aims to significantly improve the energy density, safety and robust storage performance of lithium batteries with reduced cost, by developing a next-generation battery with lithium-rich layered oxide cathodes and titanium oxide-based and silicon-based anodes. Intelligent features will make the whole energy network a next-generation battery storage system, with mechanisms to protect the battery from hazardous and inefficient operating conditions. This lithium ion battery storage system is expected to create opportunities for businesses that harvest renewable energy and make existing industries more environmentally benign.			

Development of novel safe lithium metal-free sulfur batteries

Years Funded:	2016 $32,000	2017 $73,000	2018 $73,000	2019 $32,000
Industry Fund:		$39,000	$26,000	$13,000

Total Funding: $288,000

Project ID: LP160100914

Chief Investigators: J. Z. Wang, H. K. Liu, K. Konstantinov, S. L. Chou

Industry Partner: Nipress TBK, PT

Project Summary: This project aims to develop a lithium-metal-free sulphur battery system, and technology to commercialise this battery technology. Expected outcomes include an electrochemical system consisting of a selected promising lithium sulphide cathode, an alloying type anode and a liquid-based electrolyte, and large lithium-ion sulphur batteries with selected advanced electrode materials and electrolytes. Anticipated outcomes are the improved safety of typical lithium-sulphur batteries; that Australia will be internationally competitive in the area of energy storage; and increased overseas demand for Australian raw materials for manufacturing lithium-ion batteries.

High energy density, long life, safe lithium ion battery for electric cars

Years Funded:	2016 $70,000	2017 $140,000	2018 $140,000	2019 $70,000
Industry Fund:		$145,000	$96,000	$49,000

Total Funding: $710,000

Project ID: LP160101629

Chief Investigators: Z. P. Guo, J. F. Mao, W. Li

Industry Partner: Tianneng Power International Limited

Project Summary: This project aims to develop next-generation lithium-ion batteries with high energy density, safety, long cycle life, and fast charge capability, using a Ni-rich layered oxide cathode and silicon/carbon composite anode. This lithium-ion battery system is expected to meet 2020 targets for electric vehicles. The project will also investigate the reaction/electrode fading mechanism of the proposed anode/cathode materials for the deep understanding of these electrode materials, and provide guidance for future electrode materials design and battery research. This will provide significant benefits for automotive industries, smart grid, and business in storing renewable energy and better environment and sustainability.

Nanostructure engineered low activation superconductors for fusion energy

Years Funded:	2016 $54,000	2017 $106,000	2018 $106,000	2019 $54,000
Industry Fund:		$55,000	$55,000	$55,000

Total Funding: $485,000

Project ID: LP160101784

Chief Investigators: M. S. A. Hossain, S. X. Dou, J. H. Kim, Y. Yamauchi, R. Taylor, V. Luzin, A. Devred

Industry Partner: QUT, ANSTO, ITER, Hyper Tech Research Inc., Pavezyum, Magnix Technologies

Project Summary: This project aims to develop a novel, low activation and liquid helium-free superconducting solution with superior electromagnetic, mechanical and thermal properties for use in fusion reactors. Superconducting magnets and their associated cryogenic cooling systems represent a key determinant of thermal efficiency and the construction/operating costs of fusion reactors. The project expects to overcome these barriers so that widespread uptake of these reactors becomes viable. Outcomes from the project will include a fundamental understanding of pure and doping-induced isotopic magnesium diboride superconductors and their behaviour under high neutron flux and harsh plasma atmosphere, which are specifically designed for application in next-generation, low-cost fusion reactors.

Liquid metal for quench detection sensors and low resistance joints

Years Funded:	2019 $47,000	2020 $90,000	2021 $83,000	2022 $42,000
Industry Fund:	$50,000	$50,000	$50,000	
Total Funding:	$412,000			
Project ID:	LP180100722			
Chief Investigators:	S. X. Dou, X. Xu, Y. Du, W. P. Sun, K. W. See, J. Zheng			
Industry Partner:	Ningbo Jansen NMR Technology Co., Ltd.			
Project Summary:	This project aims to develop next-generation liquid metal-based superconducting joints and quench detection sensors to enable superconducting magnets to operate in “persistent mode”. This would make a significant contribution to improving the safety and performance of superconducting coil systems at a reduced cost. Furthermore, intelligent features will be formulated to prevent hazardous and inefficient operating conditions. The expected outcome is that an advanced superconducting coil system with improved stability and safety is delivered with newly developed liquid metal-based materials and relevant fabrication techniques.			

OTHER GRANTS

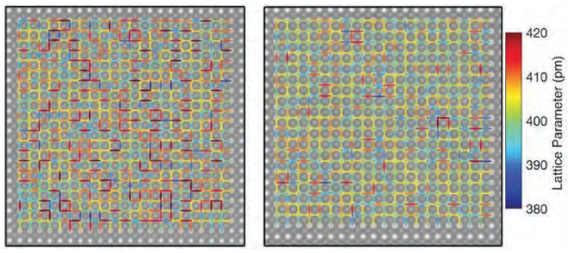
Australian Renewable Energy Agency

The Smart Sodium Storage Solution (S4) Project

Years Funded:	2016 $579,500	2017 $869,500	2018 $1,328,000	2019 $1,181,500	2020 $558,500
Total Funding:	$4,517,000				
Chief Investigators:	S. X. Dou, H. K. Liu, S. L. Chou, K. W. See, D. Soetanto, K. Muttaqi, S. Ville				
Project Summary:	This project will develop and integrate a new type of sodium-ion battery in a low-cost, modular and expandable energy storage system to be demonstrated at the Illawarra Flame House and Sydney Water’s Bondi Sewage Pumping Station. This project will develop a new sodium-ion battery architecture, optimised for use in renewables storage applications, by building on the world-class energy materials research and deep industry ties of the Institute for Superconducting and Electronic Materials (ISEM). Facilities at the ISEM used to prototype and characterise the sodium-ion batteries for ISEM’s industry-leading researchers will be upgraded and expanded to support the rapid development of the battery architecture. A modular, expandable packaging system with integrated battery and thermal management systems will be developed, produced and validated through two applications: a 5 kWh battery at Illawarra Flame House, an award-winning net-zero energy home, and a 30 kWh integrated battery and energy management system at Sydney Water’s Bondi Sewage Pumping Station. The Sydney Water site will also have an energy management system developed as part of this project, which will integrate and manage renewable energy generation, storage and consumption in an efficient manner by utilising intelligent algorithms and control strategies. The Sydney Water site will demonstrate the turn-key nature of the system and highlight the suitability of sodium-ion batteries for use in utility applications.				

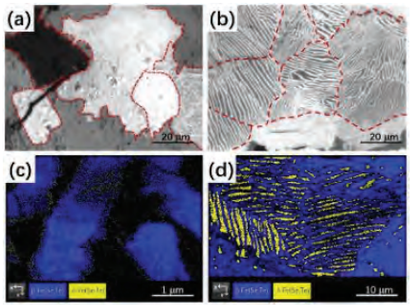
Selected Abstracts

Giant piezoelectricity of Sm-doped $Pb(Mg_{1/3}Nb_{2/3})O_3$-$PbTiO_3$ single crystals



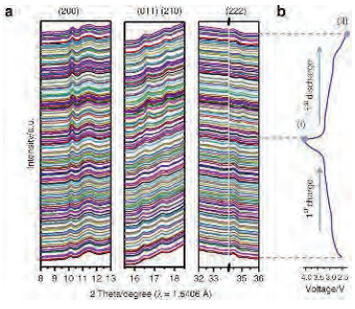
High-performance piezoelectrics benefit transducers and sensors in a variety of electromechanical applications.The materials with the highest piezoelectric charge coefficients (d33) are relaxor-$PbTiO_3$ crystals, which were discovered two decades ago. We successfully grew Sm-doped $Pb(Mg_{1/3}Nb_{2/3})O_3$-$PbTiO_3$ (Sm-PMN-PT) single crystals with even higher d33 values ranging from 3400 to 4100 picocoulombs per newton, with variation below 20% over the as-grown crystal boule, exhibiting good property uniformity.We characterized the Sm-PMN-PTon the atomic scale with scanning transmission electron microscopy and made first-principles calculations to determine that the giant piezoelectric properties arise fromthe enhanced local structural heterogeneity introduced by Sm^{3+} dopants. Rare-earth doping is thus identified as a general strategy for introducing local structural heterogeneity in order to enhance the piezoelectricity of relaxor ferroelectric crystals. (F. Li et al., ***Science*** 364, 264 (2019))

Boosting superconducting properties of Fe(Se, Te) via dual-oscillation phenomena induced by fluorine doping



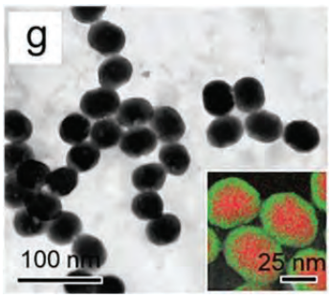
Fluorine-doped Fe(Se, Te) has been successfully synthesized using the melting method. A dual-oscillation effect was found in the Fdoped sample, which combined both microstructural oscillation and chemical compositional oscillation. The microstructural oscillation could be attributed to alternate growth of tetragonal β-Fe(Se, Te) and hexagonal δ-Fe(Se, Te), which formed a pearlite-like structure and led to the enhancement of δl flux pinning due to the alternating distributed nonsuperconducting δ-Fe(Se, Te) phase. The chemical compositional oscillations in β-Fe(Se, Te) phase were because of the inhomogeneously distributed Se and Te, which changes the pinning mechanism from surface pinning in the undoped sample to Δκ pinning in the 5% F-doped one. As a result, the critical current, upper critical field, and thermally activated fluxflow activation energy of $FeSe_{0.45}Te_{0.5}F_{0.05}$ were enhanced by 7, 2, and 3 times, respectively. Our work revealed the physical insights into F-doping resulting in high-performance Fe(Se, Te) superconductors and inspired a new approach to optimize superconductivities in iron-based superconductors through phase and element manipulations. (J. X. Liu et al., ***ACS Applied Materials & Interfaces*** 11, 18825 (2019))

NASICON-type air-stable and all-climate cathode for sodium-ion batteries with low cost and high-power density



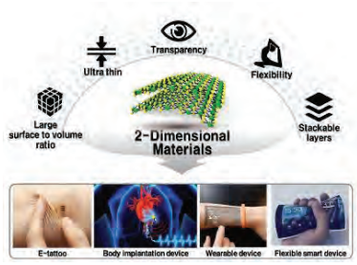
The development of low-cost and long-lasting all-climate cathode materials for the sodium ion battery has been one of the key issues for the success of large-scale energy storage. One option is the utilization of earth-abundant elements such as iron. Here, we synthesize a NASICON-type tuneable $Na_4Fe_3(PO_4)_2(P_2O_7)$/C nanocomposite which shows both excellent rate performance and outstanding cycling stability over more than 4400 cycles. Its air stability and all-climate properties are investigated, and its potential as the sodium host in full cells has been studied. A remarkably low volume change of 4.0% is observed. Its high sodium diffusion coefficient has been measured and analysed via first-principles calculations, and its three-dimensional sodium ion diffusion pathways are identified. Our results indicate that this low-cost and environmentally friendly $Na_4Fe_3(PO_4)_2(P_2O_7)$/C nanocomposite could be a competitive candidate material for sodium ion batteries.. (M. Z. Chen et al., ***Nature Communications*** 10, 1480 (2019))

Near-infrared-driven photocatalysts: Design, construction, and applications



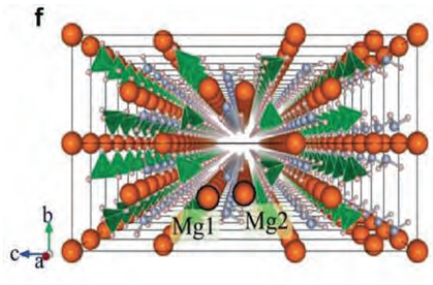
Photocatalysts, which utilize solar energy to catalyze the oxidation or reduction half reactions, have attracted tremendous interest due to their great potential in addressing increasingly severe global energy and environmental issues. Solar energy utilization plays an important role in determining photocatalytic efficiencies. In the past few decades, many studies have been done to promote photocatalytic efficiencies via extending the absorption of solar energy into near-infrared (NIR) light. This Review comprehensively summarizes the recent progress in NIR-driven photocatalysts, including the strategies to harvest NIR photons and corresponding photocatalytic applications such as the degradation of organic pollutants, water disinfection, water splitting for H_2 and O_2 evolution, CO_2 reduction, etc. The application of NIR-active photocatalysts employed as electrocatalysts is also presented. The subject matter of this Review is designed to present the relationship between material structure and material optical properties as well as the advantage of material modification in photocatalytic reactions. It paves the way for future material design in solar energy–related fields and other energy conversion and storage fields. (L. Wang et al., ***Small***, 1904107 (2019))

Piezo/triboelectric nanogenerators based on 2-dimensional layered structure materials



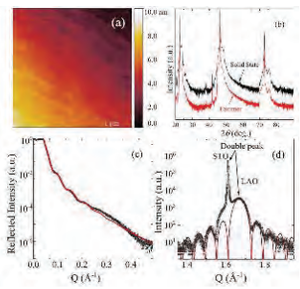
Recently, research on energy harvesting has attracted great attention as a solution to energy depletion and environmental problems due to the use of fossil fuels such as coal, natural gas, and oil. To be precise, harvesting technology converts the energy sources around us such as solar, heat, and mechanical energy into electrical energy. It has the advantage of being able to supply and sustain energy on a permanent basis, rather than being non-renewable, and it is also eco-friendly. Among the various energy harvesting techniques, nanogenerators based on piezoelectric and triboelectric phenomena can generate electrical energy based on mechanical energy sources, which are usually ubiquitous, there are no restrictions due to weather, time, or space, and this technology is also user-friendly. Recently, two-dimensional (2D) materials have been chosen for implementing piezo/triboelectric nanogenerators. The 2D materials have transparency, flexibility, and a high surface-to-volume ratio. Owing to the very low thickness of the atomic unit, a stacking structure using 2D materials can be also made to form a very thin device, which is applicable for insertion into the body or wearable electronic devices. In this review, we summarize the characteristics and research results on piezo/triboelectric energy harvesters based on 2D layered structure materials. (S. A. Han et al., ***Nano Energy*** 57, 680 (2019))

Borohydride-scaffolded Li/Na/Mg fast ionic conductors for promising solid-state electrolytes



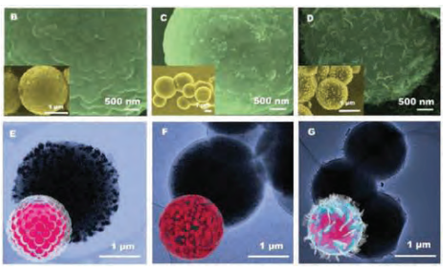
Borohydride solid-state electrolytes with room-temperature ionic conductivity up to ≈70 mS cm−1 have achieved impressive progress and quickly taken their place among the superionic conductive solid-state electrolytes. Here, the focus is on state-of-the-art developments in borohydride solid-state electrolytes, including their competitive ionic-conductive performance, current limitations for practical applications in solid-state batteries, and the strategies to address their problems. To open, fast Li/Na/Mg ionic conductivity in electrolytes with BH4 − groups, approaches to engineering borohydrides with enhanced ionic conductivity, and later on the superionic conductivity of polyhedral borohydrides, their correlated conductive kinetics/thermodynamics, and the theoretically predicted high conductive derivatives are discussed. Furthermore, the validity of borohydride pairing with coated oxides, sulfur, organic electrodes, MgH2, TiS2, Li4Ti5O12, electrode materials, etc., is surveyed in solid-state batteries. From the viewpoint of compatible cathodes, the stable electrochemical windows of borohydride solid-state electrolytes, the electrode/electrolyte interface behavior and battery device design, and the performance optimization of borohydride-based solid-state batteries are also discussed in detail. A comprehensive coverage of emerging trends in borohydride solid-state electrolytes is provided and future maps to promote better performance of borohydride SSEs are sketched out, which will pave the way for their further development in the field of energy storage. (J. Cuan et al., ***Advanced Materials*** 31, 1803533 (2019))

Partial carrier freeze-out at the $LaAlO_3/SrTiO_3$ oxide interface



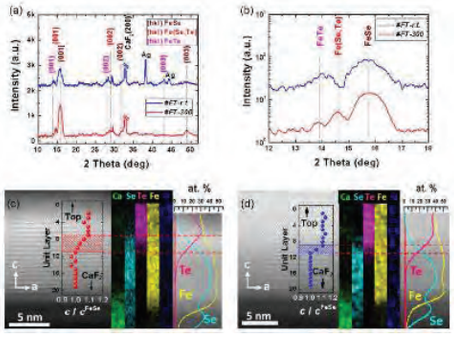
High quality robust two-dimensional electron gas (2DEG) $LaAlO_3/SrTiO_3$ (LAO/STO) interfaces are produced using pulsed laser deposition and an acid-free substrate Ti-termination process, resulting in single unit cell terraces. Temperature dependent resistance measurements show two hysteresis anomalies around 80 K and 160 K. By using Hall measurements, we find an Arrhenius dependence in charge carrier density describing a partial carrier freeze-out below ~80 K. We show that these two resistance anomalies are unrelated to the temperature dependence of the charge carrier density despite the tempting coincidence of the low temperature hysteresis feature and the freeze-out process. A twocarrier model is required to accurately estimate the activation energy of the thermally activated type charge carriers, which are found to be ~5 to 7 meV. These results support the theory that oxygen vacancy defects contribute to the metallic conductivity at the 2DEG LAO/STO interface even for annealed samples. (S. Meaney et al., ***APL Materials*** 7, 101105 (2019))

Structural engineering of hierarchical micronanostructured Ge–C framework by controlling the nucleation for ultralong-life Li storage



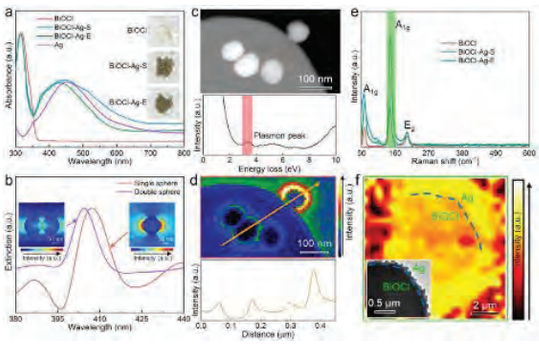
The rational design of a proper electrode structure with high energy and power densities, long cycling lifespan, and low cost still remains a significant challenge for developing advanced energy storage systems. Germanium is a highly promising anode material for high-performance lithium ion batteries due to its large specific capacity and remarkable rate capability. Nevertheless, poor cycling stability and high price significantly limit its practical application. Herein, a facile and scalable structural engineering strategy is proposed by controlling the nucleation to fabricate a unique hierarchical micro-nanostructured Ge–C framework, featuring high tap density, reduced Ge content, superb structural stability, and a 3D conductive network. The constructed architecture has demonstrated outstanding reversible capacity of 1541.1 mA h g^{-1} after 3000 cycles at 1000 mA g^{-1} (with 99.6% capacity retention), markedly exceeding all the reported Ge–C electrodes regarding long cycling stability. Notably, the assembled full cell exhibits superior performance as well. The work paves the way to constructing novel metal–carbon materials with high performance and low cost for energy-related applications. (S. L. Zhang et al., ***Advanced Energy Materials*** 9, 1900081 (2019))

Enhanced superconductivity induced by several-unit-cells diffusion in an FeTe/FeSe bilayer heterostructure



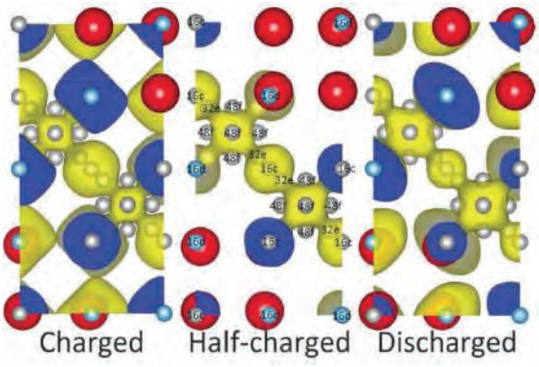
Unlike monolayer Fe-Chalcogenide (Fe-*Ch*)/$SrTiO_3$ (STO), which possesses the potential for hightemperature superconductivity (HTS), a regular Fe-*Ch* thin film grown on a non-STO substrate by the pulsed laser deposition method shows totally different superconducting behavior and a different mechanism. Although regular Fe-*Ch* thick films grown on CaF_2 generally show the highest superconducting transition temperature (*Tc*) compared with any other substrates, the disappearance of superconductivity always takes place when the thickness of the Fe-*Ch* film is reduced to a critical value (~20 nm for Fe-Se and ~30 nm for Fe-Se-Te) with the reason still under debate. Here, we report an enhanced *Tc* ≈ 17.6K in a 7-nm-FeTe/7-nm-FeSe bilayer heterostructure grown on CaF_2 substrate. Generally, the Fe-*Ch* film on CaF_2 is supposed to be one order of magnitude greater in thickness to achieve similar performance. Hall measurements manifest the dominant nature of hole-type carriers in the films in this work, which is similar to the case of a pressurized bulk FeSe single crystal, while in sharp contrast to heavily electron-doped HTS Fe-*Ch* systems. According to the electron energy loss spectroscopy results, we observed direct evidence of nanoscale phase separation in the form of a fluctuation of the Fe-*L3*/*L2* ratio near the FeTe/FeSe interface. In detail, a several-unit-cell-thick Fe(Se,Te) diffusion layer shows a higher Fe-*L3*/*L2* ratio than either an FeTe or an FeSe layer, indicating low Fe 3*d* electron occupancy, which is, to some extent, consistent with the hole-dominant scenario obtained from the Hall results. It also implies a possible relationship between the state of Fe 3*d* electron occupancy and the enhanced *Tc* in this work. Our work clarifies the importance of the FeTe/FeSe interface in reviving the superconductivity in Fe-*Ch* ultrathin films, contributing to a more unified understanding of unconventional Fe-*Ch* superconductivity. (W. B. Qiu et al., ***Physical Review B*** 99, 064502 (2019))

Promoting photoreduction properties via synergetic utilization between plasmonic effect and highly active facet of BiOCl



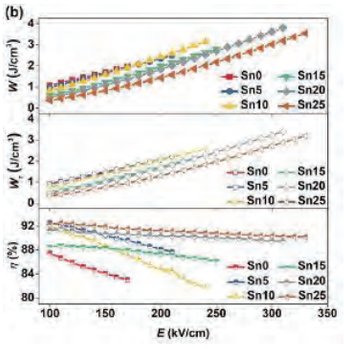
Exploring highly efficient photocatalysts is an urgent task for achieving efficient solar-to-chemical conversion. Plasmonic effect is widely used in improving the photocatalytic properties via reducing the activation barrier for chemical reactions, enhancing the absorption of the photocatalysts or injecting the hot carriers into the photocatalysts from the plasmon metals. In this work, we design BiOCl-Ag-E with Ag loaded on the edge side of BiOCl. This hybrid structure takes the advantages of highly photocatalytic active (001) facet of BiOCl and the plasmonic effect. The plasmon metal is proposed to provide the (001) facets with more photogenerated charge carriers driving by the internal electric field, which is convinced by the photocurrent response and the detection of active species. Due to the accumulation of more negative charge carriers on (001) facet, BiOCl-Ag-E presents outstanding waste-water cleaning and CO_2 photoreduction properties. The methodology of material design in this work paves the way for future design of efficient photocatalysts. (L. Wang et al., ***Nano Energy*** 57, 398 (2019))

Understanding rechargeable battery function using in operando neutron powder diffraction



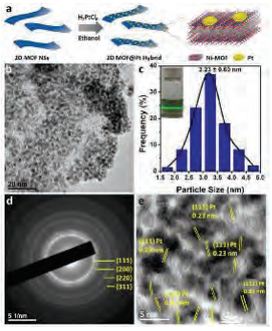
The performance of rechargeable batteries is influenced by the structural and phase changes of components during cycling. Neutron powder diffraction (NPD) provides unique and useful information concerning the structure–function relation of battery components and can be used to study the changes to component phase and structure during battery cycling, known as in operando measurement studies. The development and use of NPD for in operando measurements of batteries is summarized along with detailed experimental approaches that impact the insights gained by these. A summary of the information gained concerning battery function using in operando NPD measurements is provided, including the structural and phase evolution of electrode materials and charge-carrying ion diffusion pathways through these, which are critical to the development of battery technology. (G. M. Liang et al., ***Advanced Materials*** 32, 1904258 (2020))

Ultra-high energy storage performance with mitigated polarization saturation in lead-free relaxors



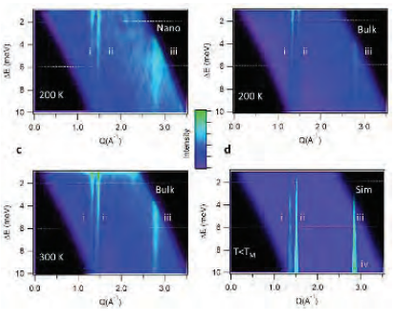
Relaxor ferroelectric ceramics have attracted much attention for storing the electricity generated from clean and renewable energy sources due to their high permittivity and near-zero remnant polarization. The polarization of many relaxor based ceramics tends to saturate at high electric fields, however, which limits their energy storage performance. In this study, a lead-free Sn-modified $(Na_{0.5}Bi_{0.5})TiO_3$–$SrTiO_3$ system is investigated, where mitigated polarization saturation is observed with the addition of Sn^{4+}, as a result of the different electronic configurations between d^{10} Sn^{4+} and d^0 Ti^{4+}. As expected, high energy density of 3.4 J cm^{-3} and energy efficiency of 90% are simultaneously achieved in $(Na_{0.25}Bi_{0.25}Sr_{0.5})(Ti_{0.8}Sn_{0.2})O_3$ ceramic. In addition, the ceramic exhibits good thermal stability, with the energy storage property variations below 5% over the temperature range of 20 °C to 150 °C, and satisfactory cycling stability with a variation of less than 8% over 105 cycles. All these merits demonstrate that the $(Na_{0.25}Bi_{0.25}Sr_{0.5})(Ti_{0.8}Sn_{0.2})O_3$ ceramic has great potential for high power energy storage applications. (L. Yang et al., ***Journal of Materials Chemistry A*** 7, 8573 (2019))

Direct hybridization of noble metal nanostructures on 2D metal–organic framework nanosheets to catalyze hydrogen evolution



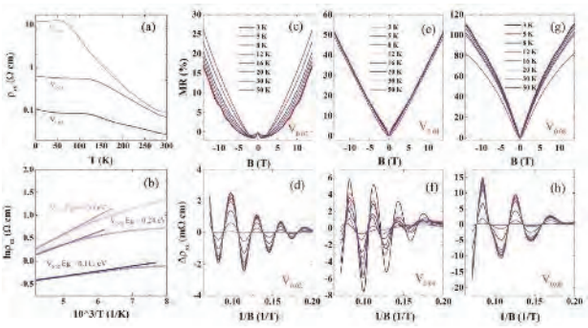
Rational hybridization of two-dimensional (2D) nanomaterials with extrinsic species has shown great promise for a wide range of applications. To date, rational design and engineering of heterostructures based on 2D metal–organic frameworks (MOFs) has been rather limited. Herein, we report an efficient strategy to construct noble metal/2D MOF heterostructures, featuring the utilization of surface oxygen sites from uncoordinated MOF ligands. The incorporation of highly dispersed noble metal nanoparticles (e.g. Pt and Pd) with modulated electronic structure is enabled on a surfactant-free MOF surface. As a proof-of-concept demonstration, the 2D Ni-MOF@Pt hybrid with well-defined interfaces is applied to boost the electrochemical hydrogen evolution reaction (HER) and delivers decent electrocatalytic activity under both acidic and alkaline conditions. The present results are expected to provide new insights into furnishing MOFs with extended functionalities and applications. (K. Rui et al., ***Nano Letters*** 19, 8447 (2019))

Spin-wave propagation in α-Fe_2O_3 nanorods: the effect of confinement and disorder



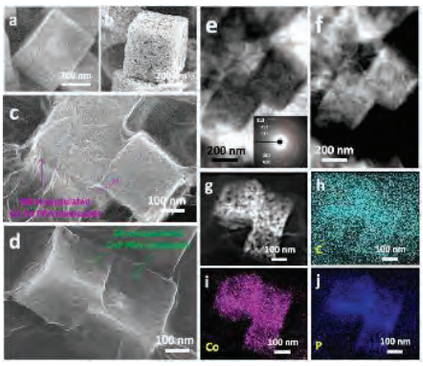
Spin-wave excitations in α-Fe_2O_3 nanorods were directly detected using time-of-flight inelastic neutron spectroscopy. The dispersive magnon features are compared with those in bulk α-Fe_2O_3 particles at various temperatures to highlight differences in mode intensity and width. The interchanged spectral intensities in the nanorod are a consequence of a suppressed spin orientation, and this is also evident in the neutron diffraction which demonstates that the weak ferromagnetic phase survives to 1.5 K. Transmission electron microscopy shows that the ellipsoidal particles are single-crystalline with a typical length of 300 ± 100 nm and diameter of 60 ± 10 nm. The main magnon features are similar in bulk and nanoforms and can be explained using a model Hamiltonian based on Samuelson and Shirane's classical theory with exchange constants of J_1 = −1.03 meV, J_2 = −0.28 meV, J_3 = 5.12 meV and J_4 = 4.00 meV. Numerical simulations show that two distinct mechanisms may contribute to the magnon line broadening in the nanorods: a distribution of exchange interactions caused by disorder, and a shortened quasiparticle lifetime caused by the scattering of spin waves at surfaces. (D. Cortie et al., ***Journal of Physics – Condensed Matter*** 31, 18403 (2019))

Quantum oscillations of robust topological surface states up to 50K in thick bulk-insulating topological insulator



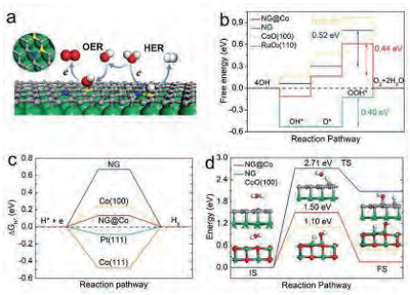
As personal electronic devices increasingly rely on cloud computing for energy-intensive calculations, the power consumption associated with the information revolution is rapidly becoming an important environmental issue. Several approaches have been proposed to construct electronic devices with low-energy consumption. Among these, the low-dissipation surface states of topological insulators (TIs) are widely employed. To develop TI-based devices, a key factor is the maximum temperature at which the Dirac surface states dominate the transport behavior. Here, we employ Shubnikov-de Haas oscillations (SdH) as a means to study the surface state survival temperature in a high-quality vanadium doped $Bi_{1.08}Sn_{0.02}Sb_{0.9}Te_2S$ single crystal system. The temperature and angle dependence of the SdH show that: (1) crystals with different vanadium (V) doping levels are insulating in the 3–300 K region; (2) the SdH oscillations show two-dimensional behavior, indicating that the oscillations arise from the pure surface states; and (3) at 50 K, the V0.04 single crystals (V_x:$Bi_{1.08-x}Sn_{0.02}Sb_{0.9}Te_2S$, where x = $_{0.04}$) still show clear sign of SdH oscillations, which demonstrate that the surface dominant transport behavior can survive above 50 K. The robust surface states in our V doped single crystal systems provide an ideal platform to study the Dirac fermions and their interaction with other materials above 50 K. (W. Y. Zhao et al., ***NPJ Quantum Materials*** 4, 56 (2019))

Three-dimensional porous cobalt phosphide nanocubes encapsulated in a graphene aerogel as an advanced anode with high Coulombic efficiency for high-energy lithium-ion batteries



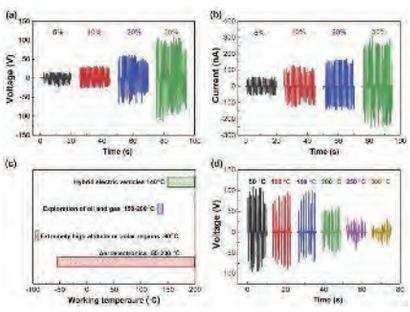
An ingeniously designed porous structure can synergistically optimize the desired properties and maximize the advantages of a material as an electrode for a high-performance energy storage system. The active material with a porous nanostructure could reduce the ion diffusion path and buffer the strain caused by the volume changes during cycling. Furthermore, combining the active material with a three-dimensional (3D) graphene aerogel (GA) matrix is an ideal way to maintain the structural integrity, improve the conductivity, and overcome the aggregation problem of the nanomaterials. Herein, we adopted a facile template-based strategy to derive a composite of 3D hierarchically porous cobalt phosphide nanocubes with a graphene aerogel (CoP@GA). The as-prepared CoP@GA features porous cobalt phosphide nanocubes that are firmly encapsulated and uniformly distributed in the well-defined graphene aerogel skeleton. Benefiting from the hierarchical porosity, structural integrity, and conductive network, the CoP@GA electrode manifests an ultrahigh initial Coulombic efficiency (88.6%), outstanding lithium storage performance in terms of excellent cycling performance (805.3 $mAh{\cdot}g^{-1}$ after 200 cycles at 200 $mA{\cdot}g^{-1}$), superior high-energy performance (351.8 $mAh{\cdot}g^{-1}$ after 4000 cycles at 10 $A{\cdot}g^{-1}$), and exceptional rate capability. Moreover, this synthesis protocol could be an instructive precedent for fabricating transition-metal-phosphide-based 3D porous composites with excellent electrochemical performances. (H. Gao et al., ***ACS Applied Materials & Interfaces*** 11, 5373 (2019))

Rational design of two-dimensional hybrid Co/Ndoped carbon nanosheet arrays for efficient bi-functional electrocatalysis



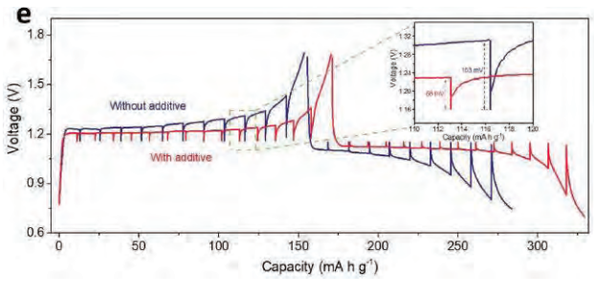
Transition metals with desirable valence states have been proposed as efficient non-noble-metal electrocatalytic systems for selective water splitting. In this work, two-dimensional (2D) nitrogen-doped leaf-like carbon matrix arrays functionalized with multi-valence-state transition metal (cobalt) hybrids were successfully prepared by in situ calcination of the corresponding bimetallic leaf-like zeolitic imidazolate framework (ZIF-L) in an inert atmosphere. The 2D morphology of the matrix along with the particle size and surface valence state of the anchored particles has been successfully controlled via precisely adjusting the $Co^{2+}/(Zn^{2+} + Co^{2+})$ ratio in the bimetallic ZIF-L precursor. Electrochemical measurements show that the kinetics of and stability towards the hydrogen evolution reaction (HER) and oxygen evolution reaction (OER) are highly dependent on the particle size as well as the valence states. It was found that the particles with sizes less than 60 nm exhibit mixed Co^0/Co^{2+}valence states, and therefore demonstrate bi-functional electrocatalytic performance. The theoretical simulations revealed that the bi-functional electrocatalytic activity should be attributed to the synergetic effect of mixed Co^0/Co^{2+} and electronic coupling in the hybrids, which are of benefit to the catalytic kinetics and dynamics. High HER and OER activities of the hybrids have been verified, in which overpotentials of 171 and 280 mV to deliver a current density of 10 mA cm^{-2} for the HER and OER, respectively, were achieved. The obtained correlation between non-noble-metal-based carbon composites and HER/OER activities may be exploited as a rational guideline in the design and engineering of electrocatalysts. (N. Y. Cheng et al., ***Sustainable Energy & Fuels*** 3, 1757 (2019))

Flexible piezoelectric energy harvester/sensor with high voltage output over wide temperature range



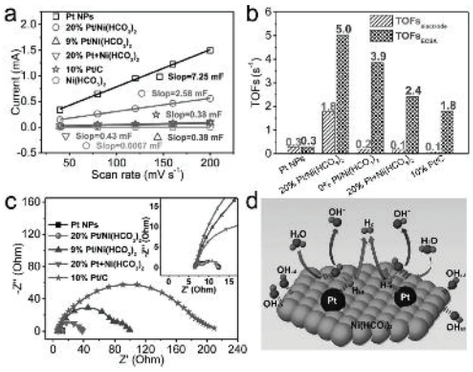
A flexible piezoelectric energy harvester based on polyimide (PI)/(Bi,La)FeO_3-$PbTiO_3$ (BLF-PT) 0–3 composite was fabricated by a cost-effective two-step process. The energy harvesting outputs are sensitive to the BLF-PT weight fraction and testing frequency. The flexible BLF-PT/PI composite with 30 wt% BLF-PT exhibits an open circuit voltage of 110 V and a short circuit current of 310 nA under pressure of 0.18 MPa at frequency of 1 Hz. Of particular significance is that the flexible energy harvester exhibits high temperature stability up to 150 °C and a voltage output of 30 V at temperatures as high as 300 °C, showing great potential for capturing mechanical energy or sensor over a wide temperature range at ultra-low frequency. (Y. H. Sun et al., ***Nano Energy*** 61, 337 (2019))

Toward high-performance hybrid Zn-based batteries via deeply understanding their mechanism and using electrolyte additive



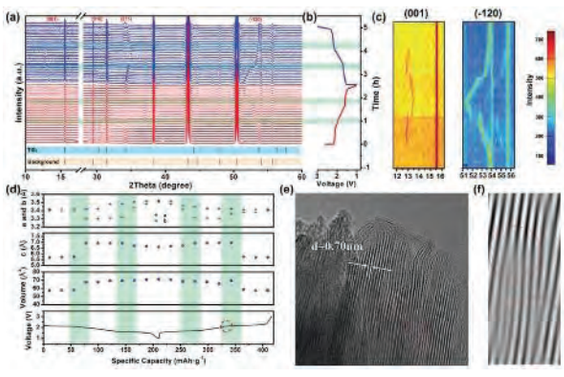
Aqueous hybrid Zn-based batteries (ZIBs), as a highly promising alternative to lithium-ion batteries for grid application, have made considerable progress recently. However, few studies have been reported that investigate their working mechanism in detail. Here, the *operando* synchrotron X-ray diffraction is employed to thoroughly investigate the operational mechanism of a hybrid $LiFePO_4$(LFP)/Zn battery, which indicates only Li^+ extraction/insertion from/into cathode during cycling. Based on this system, a cheap electrolyte additive, sodium dodecyl benzene sulfonate, is proposed to effectively enhance its electrochemical properties. The influence of the additive on the Zn anode and LFP cathode is comprehensively studied, respectively. The results show that the additive modifies the intrinsic deposit pattern of Zn^{2+} ions, rendering Zn plating/stripping highly reversible in an aqueous medium. On the other hand, the wettability of the LFP electrode is visibly a meliorated by introducing the surfactant additive, accelerating the Li-ion diffusion at the LFP electrode/electrolyte interface, as indicated by the overpotential measurements. Benefiting from these effects, the Zn/LFP batteries deliver high rate capability and cycling stability in both coin cells and pouch cells. (J. N. Hao et al., ***Advanced Functional Materials*** 29, 1903605 (2019))

Platinum/nickel bicarbonate heterostructures towards accelerated hydrogen evolution under alkaline conditions



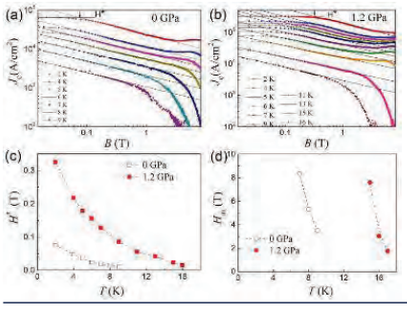
Heterostructured nanomaterials, generally have physicochemical properties that differ from those of the individual components, and thus have potential in a wide range of applications. New platinum (Pt)/nickel bicarbonate ($Ni(HCO_3)_2$) heterostructures are designed for an efficient alkaline hydrogen evolution reaction (HER). Notably, the specific and mass activity of Pt in Pt/$Ni(HCO_3)_2$ are substantially improved compared to the bare Pt nanoparticles (NPs). The $Ni(HCO_3)_2$ provides abundant water adsorption/dissociation sites and modulate the electronic structure of Pt, which determine the elementary reaction kinetics of alkaline HER. The $Ni(HCO_3)_2$ nanoplates offer a platform for the uniform dispersion of Pt NPs, ensuring the maximum exposure of active sites. The results demonstrate that, $Ni(HCO_3)_2$ is an effective catalyst promoter for alkaline HER. (M. M. Lao et al., ***Angewandte Chemie International Edition*** 58, 5432 (2019))

Ultrathin 2D TiS_2 nanosheets for high capacity and long-life sodium ion batteries



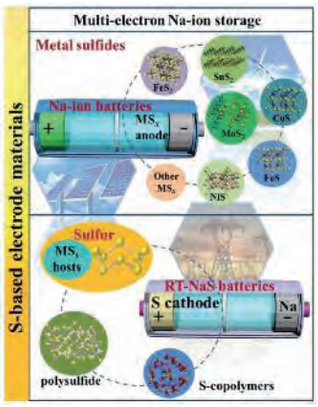
Sodium ion batteries are now attracting great attention, mainly because of the abundance of sodium resources and their cheap raw materials. 2D materials possess a unique structure for sodium storage. Among them, transition metal chalcogenides exhibit significant potential for rechargeable battery devices due to their tunable composition, remarkable structural stability, fast ion transport, and robust kinetics. Herein, ultrathin TiS_2 nanosheets are synthesized by a shear-mixing method and exhibit outstanding cycling performance (386 mAh g^{-1} after 200 cycles at 0.2 A g^{-1}). To clarify the variations of galvanostatic curves and superior cycling performance, the mechanism and morphology changes are systematically investigated. This facile synthesis method is expected to shed light on the preparation of ultrathin 2D materials, whose unique morphologies could easily enable their application in rechargeable batteries. (Z. Hu et al., ***Advanced Energy Materials*** 9, 1803210 (2019))

In-situ hydrostatic pressure induced significant suppression of magnetic relaxation and enhancement of flux pinning in $Fe_{1-x}Co_xSe_{0.5}Te_{0.5}$ single crystals



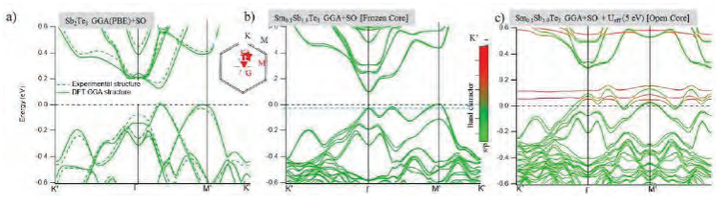
We report the first study on the significant effect of in-situ hydrostatic pressure on the magnetic relaxation in $Fe_{1-x}Co_xSe_{0.5}Te_{0.5}$ single crystals. We find that vortex creep rates are significantly suppressed by pressure, and a crossover from elastic to plastic creep is observed. The pressure also induces vortex creep to move from the large bundle to the small bundle region. Our study indicates that in-situ hydrostatic pressure is very effective for not only significantly increasing the pinning energy and the critical current density, but also reducing the size of flux bundles to suppress the decrease in current density from vortex motion. (L. N. Sang et al., ***Scripta Materialia*** 171, 57 (2019))

Sulfur-based electrodes that function via multielectron reactions for room-temperature sodium-ion storage



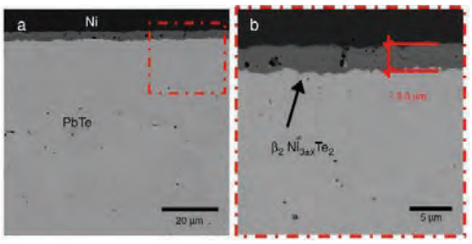
Emerging rechargeable sodium-ion storage systems—sodium-ion and room-temperature sodium–sulfur (RT-NaS) batteries—are gaining extensive research interest as low-cost options for large-scale energystorage applications. Owing to their abundance, easy accessibility, and unique physical and chemical properties, sulfur-based materials, in particular metal sulfides (MSx) and elemental sulfur (S), are currently regarded as promising electrode candidates for Na-storage technologies with high capacity and excellent redox reversibility based on multielectron conversion reactions. Here, we present current understanding of Na-storage mechanisms of the S-based electrode materials. Recent progress and strategies for improving electronic conductivity and tolerating volume variations of the MSx anodes in Na-ion batteries are reviewed. In addition, current advances on S cathodes in RT-NaS batteries are presented. We outline a novel emerging concept of integrating MSx electrocatalysts into conventional carbonaceous matrices as effective polarized S hosts in RT-NaS batteries as well. This comprehensive progress report could provide guidance for research toward the development of S-based materials for the future Na-storage techniques. (Y. X. Wang et al., ***Angewandte Chemie International Edition*** 58, 18324 (2019))

Modulation of crystal and electronic structures in topological insulators by rare-earth doping



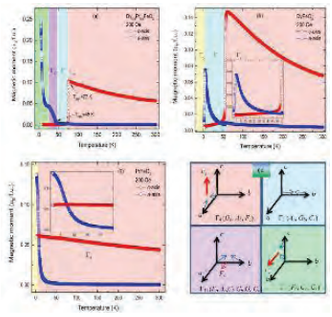
We study magnetotransport in a rare-earth-doped topological insulator, $Sm_{0.1}Sb_{1.9}Te_3$ single crystals, under magnetic fields up to 14 T. It is found that that the crystals exhibit Shubnikov–de Haas (SdH) oscillations in their magnetotransport behavior at low temperatures and high magnetic fields. The SdH oscillations result from the mixed contributions of bulk and surface states. We also investigate the SdH oscillations in different orientations of the magnetic field, which reveal a three-dimensional Fermi surface topology. By fitting the oscillatory resistance with the Lifshitz–Kosevich theory, we draw a Landau-level fan diagram that displays the expected nontrivial phase. In addition, the density functional theory calculations show that Sm doping changes the crystal structure and electronic structure compared with those of pure Sb_2Te_3. This work demonstrates that rare-earth doping is an effective way to manipulate the Fermi surface of topological insulators. Our results hold potential for the realization of exotic topological effects in magnetic topological insulators. (Z. J. Yue et al., ***ACS Applied Electronic Materials*** 1, 1929 (2019)) or ***Physical Review B*** 99, 165133 (2019)

Rapid fabrication of diffusion barrier between metal electrode and thermoelectric materials using current-controlled spark plasma sintering technique



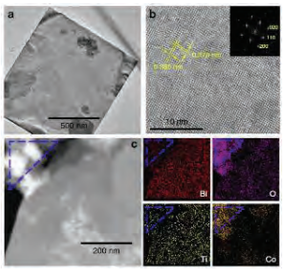
A continuous, stable diffusion barrier between PbTe thermoelectric material and Ni conduct-ing electrode was generated using the current-controlled spark plasma sintering technique.This new method creates a diffusion barrier layer by utilising the melt generated in the areaof contact between components, also called the weld nugget in a resistance spot welding pro-cess. The current-controlled spark plasma sintering process bonds the solid workpieces in afraction of the time required to fabricate interphase layers using powder components withthe common temperature-controlled spark plasma sintering. The substantially reducedtime of bonding compared to previous methods is beneficial to the thermoelectric prop-erties of materials due to their limited exposure to high temperatures, which occasionallyare much higher than the operating temperatures of devices. This work introduces a rapidand efficient bonding technique that can be applied to a wide variety of materials. (X. R. Ferreres et al., ***Journal of Materials Research and Technology*** 8, 8 (2019))

Magnetic interaction between Pr^{3+} and Dy^{3+} spins and their spin transition induced by magnetic field in a $Dy_{0.5}Pr_{0.5}FeO_3$ single crystal



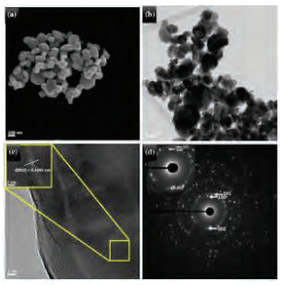
Rare-earth orthoferrites are receiving ever-increasing attention for their potential applications in magneto-optical switching, multiferroics, and novel physics originating from complicated interactions between magnetic rare-earth and iron ions. In this work, a $Dy_{0.5}Pr_{0.5}FeO_3$ single crystal was studied in comparison with $DyFeO_3$ and $PrFeO_3$ single crystals to ascertain the effects of interactions between rare-earth spins in $Dy_{0.5}Pr_{0.5}FeO_3$ on its magnetic properties. Dy^{3+} and Pr^{3+} spins do not behave as separate entities in $Dy_{0.5}Pr_{0.5}FeO_3$. The interaction between them was found to be the strongest below their antiferromagnetic ordering temperature. However, this interaction still persists to substantially higher temperatures. While the ordering temperature of Dy^{3+} spins is fieldindependent for $DyFeO_3$, it becomes strongly field-dependent for $Dy_{0.5}Pr_{0.5}FeO_3$. External field produces field polarization of nonordered rare-earth spins below ~25 K for all three systems. High-field-induced spin transition of rare-earth spins was observed for $Dy_{0.5}Pr_{0.5}FeO_3$ when a large field H ≥ 3.5 T is oriented along the crystalline a-axis at temperatures below and above the ordering temperature of the rare-earth spins, while the Fe3+ spin structure was not affected. This is different from the field-induced spin reorientation of the Dy^{3+} spin structure in $DyFeO_3$, which occurs only when Dy^{3+} spins are ordered. The complicated behavior of rare earths uncovered in this work further deepens the understanding of such a complex material system. (M. H. Mohammed et al., ***Journal of Physical Chemistry C*** 123, 30584 (2019))

Enhancing oxygen evolution efficiency of multiferroic oxides by spintronic and ferroelectric polarization regulation



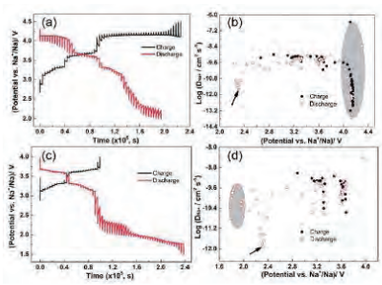
Regulating the electronic structure of catalysts is the most efficient strategy yet, despite its limitations, to improve their oxygen evolution efficiency. Instead of only adjusting the electronic structure, here we utilize ferroelectric polarization to accelerate the oxygen evolution reaction as well. This is demonstrated on a multiferroic layered perovskite $Bi_5CoTi_3O_{15}$ with in-situ grown $BiCoO_3$. Thanks to the superimposed effects of electronic regulation and ferroelectric polarization, the as-prepared multiferroic electrocatalysts are more efficient than the benchmark IrO_2 (with a final 320 mV overpotential at the current density of 10 mA cm^{-2} and a 34mV dec^{-1} Tafel slope). This work not only demonstrates a low-cost and high-efficient OER electrocatalyst, but also provides a strategic design for multicomponent electrocatalytic material systems by consideration of both spin and polarization degrees of freedom. (X. N. Li et al., ***Nature Communications*** 10, 1409 (2019))

Na-doped ZnO UV filters with reduced photocatalytic activity for sunscreen applications



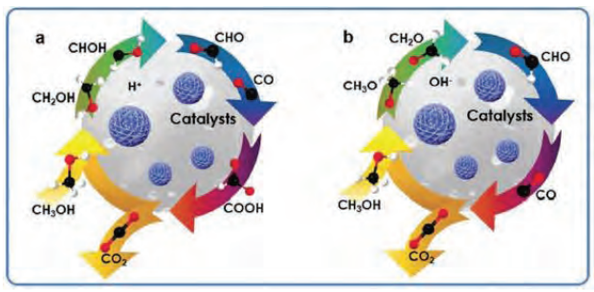
Due to its physical and chemical stability in addition to its transparency in the visible region with ultraviolet protective activity, ZnO can be used in sunscreen applications. In our article, Na-doped zinc oxide nanoparticles were prepared in different concentrations by sol–gel and solvothermal techniques to reduce their photocatalytic activity. The photocatalytic activity of the doped samples was suppressed effectively at a concentration of 0.03 at% Na doping up to 90% by conducting the sol–gel process rather than the solvothermal process which resulted in about 70% photocatalytic reduction in a period of time from (0–30 min) when exposed to ultraviolet and visible light. In addition, the nanoparticles resulted by sol–gel route show a reduction in photoactivity under solar simulation about 98% rather than those resulted via solvothermal process which shows a reduction around 92% for 30 min which is the same period of time used for the photocatalytic degradation test. The particle size was around 64.6–84.6 nm for samples prepared by both methods. (R. Mueen et al., ***Journal of Materials Science*** 55, 2772 (2019))

P2-type $Na_{2/3}Ni_{1/3}Mn_{2/3}O_2$ as a cathode material with high-rate and long-life for sodium ion storage



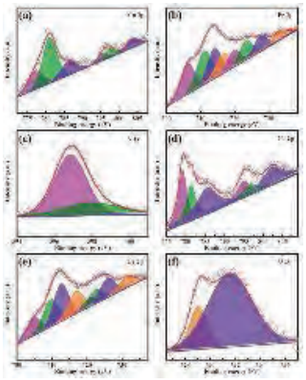
Layered P2-type $Na_{2/3}Ni_{1/3}Mn_{2/3}O_2$ was successfully synthesized through a facile sol–gel method and subsequent heat treatment. Resulting from different phase transformation and sodium ion diffusion rates, its electrochemical performance is highly related to the cut-off voltage and the electrolyte used. When the cut-off voltage is set up to 4.5 V or lowered to 1.5 V, capacity fade happens due to the occurrence of P2–O2 transformation and electrolyte decomposition or the redox reaction of the Mn^{4+}/Mn^{3+} ionic pair and P2–P20 transformation. The electrode maintained 89.0 mA h g^{-1} with good cycling stability and excellent structural preservation between 4.0 and 2.0 V. The capacity retention is 71.2% even after 1200 cycles at 10C. It can be expected that P2-type $Na_{2/3}Ni_{1/3}Mn_{2/3}O_2$ is very promising as a cathode material for sodium ion batteries. (Q. N. Liu et al., ***Journal of Materials Chemistry A*** 7, 9215 (2019))

Metal-based electrocatalysts for methanol electro-oxidation: Progress, opportunities, and challenges



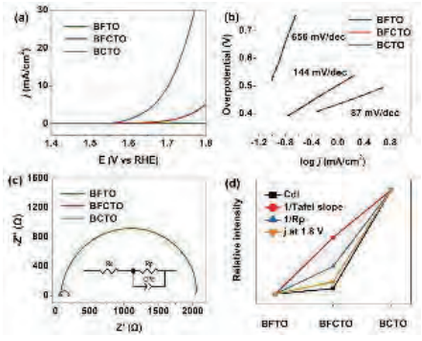
Direct methanol fuel cells (DMFCs) are among the most promising portable power supplies because of their unique advantages, including high energy density/mobility of liquid fuels, low working temperature, and low emission of pollutants. Various metal-based anode catalysts have been extensively studied and utilized for the essential methanol oxidation reaction (MOR) due to their superior electrocatalytic performance. At present, especially with the rapid advance of nanotechnology, enormous efforts have been exerted to further enhance the catalytic performance and minimize the use of precious metals. Constructing multicomponent metal-based nanocatalysts with precisely designed structures can achieve this goal by providing highly tunable compositional and structural characteristics, which is promising for the modification and optimization of their related electrochemical properties. The recent advances of metal-based electrocatalytic materials with rationally designed nanostructures and chemistries for MOR in DMFCs are highlighted and summarized herein. The effects of the well-defined nanoarchitectures on the improved electrochemical properties of the catalysts are illustrated. Finally, conclusive perspectives are provided on the opportunities and challenges for further refining the nanostructure of metal-based catalysts and improving electrocatalytic performance, as well as the commercial viability. (Y. Y. Tong et al., ***Small***, 1904126 (2019))

Metallic state two-dimensional holey-structured Co_3FeN nanosheets as stable and bifunctional electrocatalysts for zinc–air batteries



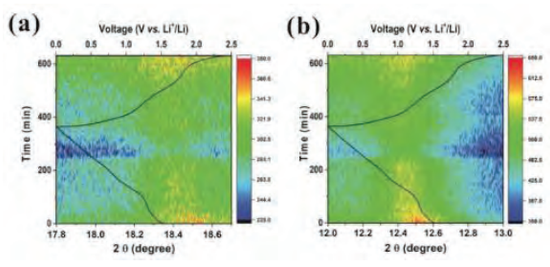
Exploring economically efficient electrocatalysts with robust bifunctional oxygen conversion catalytic activity and designing appropriate structures are essential to realize ideal zinc–air batteries with high energy density and long lifespan. Two-dimensional metallic state Co_3FeN nanosheets with a holeystructured architecture are designed and shown to exhibit enhanced catalytic properties owing to the complete exposure of the atoms in the large lateral surfaces and in the edges of pore areas, together with the lowest OH* adsorption energy on exposed surfaces due to bimetallic synergistic effects. Meanwhile, this porous architecture can not only accelerate electron transportation by its metallic state highly oriented crystallized structure, but also facilitate the diffusion of intermediates and gases. These edge-enriched 2D holey Co_3FeN nanosheets exhibit enhanced catalytic activity towards reversible oxygen conversion. When employed in zinc–air batteries, they exhibit a maximum power density of 108 mW cm^{-2} and cycle life up to 900 cycles with a low round-trip voltage of 0.84 V. The Co_3FeN nanosheets maintain a strong stable structure in an oxygen-rich electrochemical environment with a high-orientation crystalline texture during the whole cycling time. This work may provide a promising candidate to promote the further development of zinc–air batteries. (H. P. Guo et al., ***Journal of Materials Chemistry A*** 7, 26549 (2019))

Optimized electronic configuration to improve the surface absorption and bulk conductivity for enhanced oxygen evolution reaction



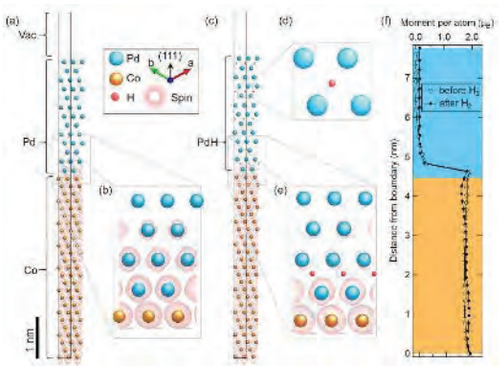
The composition and structure are crucial for stabilizing an appropriate electronic configuration (unit eg electron for example) in highefficiency electrocatalysts for the oxygen evolution reaction (OER). Here, an excellent platform to investigate the roles of the composition and structure in tuning the electron configuration for higher OER efficiency is provided by layered perovskite oxides with subtle variations of composition and structure (doping with 0%, 50%, and 100% cobalt in the $Bi_7Fe_3Ti_3O_{21}$). The crystal structures were analyzed by X-ray diffraction refinement, and the electronic structures were calculated based on X-ray absorption spectroscopy and magnetization vs temperature plots according to the Curie−Weiss law. The results indicate that the elongation of oxygen octahedra along the c-axis in layered perovskite could stabilize Co ions in the intermediate spin (IS) (t2g)5(eg)1 state, resulting in dramatically enhanced electronic conductivity and absorption capacity. Subsequently, the OER efficiency of sample with 100% Co was found to be (incredibly) 100 times higher than that of the sample with 0% Co, with the current density increased from 0.13 to 43 mA/cm^2 (1.8 V vs reversible hydrogen electrode); the Tafel slope was reduced from 656 to 87 mV/dec; and doublelayer capacity enhanced from 174 to 4193 μF/cm^2. This work reveals that both the composition and structure should be taken into account to stabilize a suitable electronic structure such as IS Co ions with moderate absorption and benign electronic conductivity for high-efficiency catalysis of the OER. (X. N. Li et al., ***Journal of the American Chemical Society*** 141, 3121 (2019))

Coupling topological insulator $SnSb_2Te_4$ nanodots with highly doped graphene for high-rate energy storage



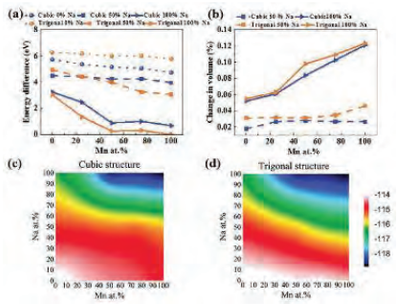
Topological insulators have spurred worldwide interest, but their advantageous properties have scarcely been explored in terms of electrochemical energy storage, and their high-rate capability and long-term cycling stability still remain a significant challenge to harvest. p-Type topological insulator $SnSb_2Te_4$ nanodots anchoring on few-layered graphene ($SnSb_2Te_4$/G) are synthesized as a stable anode for high-rate lithium-ion batteries and potassium-ion batteries through a ball-milling method. These $SnSb_2Te_4$/G composite electrodes show ultralong cycle lifespan (478 mAh g^{-1} at 1 A g^{-1} after 1000 cycles) and excellent rate capability (remaining 373 mAh g^{-1} even at 10 A g^{-1}) in Li-ion storage owing to the rapid ion transport accelerated by the PN heterojunction, virtual electron highways provided by the conductive topological surface state, and extraordinary pseudocapacitive contribution, whose excellent phase reversibility is confirmed by synchrotron in situ X-ray powder diffraction. Surprisingly, durable lifespan even at practical levels of mass loading (>10 mg cm^{-2}) for Li-ion storage and excellent K-ion storage performance are also observed. This work provides new insights for designing high-rate electrode materials by boosting conductive topological surfaces, atomic doping, and the interface interaction. (Z. B. Wu et al., ***Advanced Materials*** 32, 1905632 (2019))

In Operando study of the hydrogen-induced switching of magnetic anisotropy at the Co/Pd interface for magnetic hydrogen gas sensing



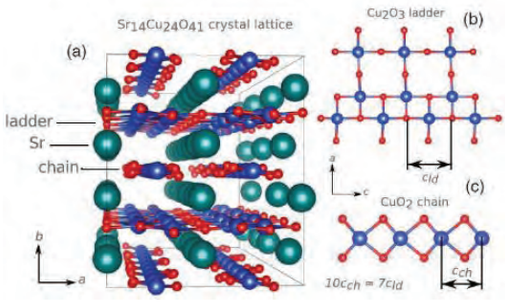
Heterostructures exhibiting perpendicular magnetic anisotropy (PMA) have traditionally served the magnetic recording industry. However, an opportunity exists to expand the applications of PMA heterostructures into the realm of hydrogen sensing using ferromagnetic resonance (FMR) by exploiting the hydrogen-induced modifications to PMA that occur at the interface between Pd and a ferromagnet. Here, we present the first in operando depth-resolved study of the in-plane interfacial magnetization of a Co/Pd film which features tailorable PMA in the presence of hydrogen gas. We combine polarized neutron reflectometry with in situ FMR to explore how the absorption of hydrogen at the Co/Pd interface affects the heterostructures spin-resonance condition during hydrogen cycling. Experimental data and modeling reveal that the Pd layer expands when exposed to hydrogen gas, while the in-plane magnetic moment of the Co/Pd film increases as the interfacial PMA is reduced to affect the FMR frequency. This work highlights a potential route for magnetic hydrogen gas sensing. (G. L. Causer et al., ***ACS Applied Materials & Interfaces*** 11, 3512 (2019))

Stress distortion restraint to boost the sodium ion storage performance of a novel binary hexacyanoferrate



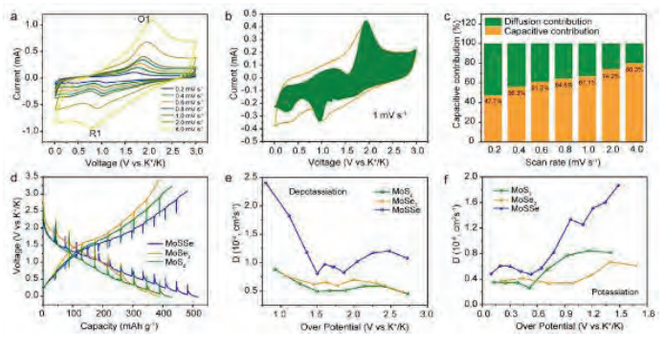
Mn-based hexacyanoferrate $Na_xMnFe(CN)_6$ (NMHFC) has been attracting more attention as a promising cathode material for sodium ion storage owing to its low cost, environmental friendliness, and its high voltage plateau of 3.6 V, which comes from the Mn^{2+}/Mn^{3+} redox couple. In particular, the Na-rich NMHFC (x > 1.40) with trigonal phase is considered an attractive candidate due to its large capacity of ≈130 mAh g^{-1}, delivering high energy density. Its unstable cycle life, however, is holding back its practical application due to the dissolution of Mn^{2+} and the trigonal-cubic phase transition during the charge–discharge process. Here, a novel hexacyanoferrate ($Na_{1.60}Mn_{0.833}Fe_{0.167}[Fe(CN)_6]$, NMFHFC-1) with Na-rich cubic structure and dual-metal active redox couples is developed for the first time. Through multiple structural modulation, the stress distortion is minimized by restraining Mn^{2+} dissolution and the trigonal-cubic phase transition, which are common issues in manganese-based hexacyanoferrate. Moreover, NMFHFC-1 simultaneously retains an abundance of Na ions in the framework. As a result, $Na_{1.60}Mn_{0.833}Fe_{0.167}[Fe(CN)_6]$ electrode delivers high energy density (436 Wh kg^{-1}) and excellent cycle life (80.2% capacity retention over 300 cycles), paving the way for the development of novel commercial cathode materials for sodium ion storage. (W. J. Li et al., ***Advanced Energy Materials*** 10, 1903006 (2019))

Effects of Ca substitution on quasiacoustic sliding modes in $Sr_{14-x}Ca_xCu_{24}O_{41}$



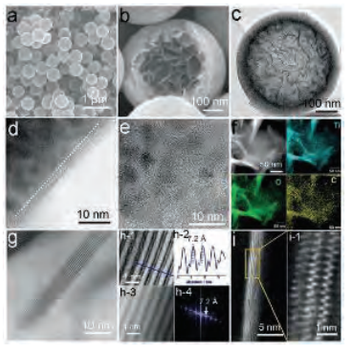
The low-energy lattice dynamics of the quasiperiodic spin-ladder cuprate $Sr_{14-x}Ca_xCu_{24}O_{41}$ are investigated using terahertz frequency synchrotron radiation. A high density of low-lying optical excitations is present in the 1–3 THz energy range, while at least two highly absorbing excitations stemming from long-wavelength acoustic oscillations of the incommensurate chain and ladder sublattices, are observed at subterahertz frequencies. The effects of Ca substitution on the subterahertz quasiacoustic sliding mode gaps is investigated using coherent synchrotron radiation. Analysis of the results suggest increasing substitution of Sr for Ca is accompanied by a transfer of spectral weight between sliding modes associated with different chain-ladder dynamics. The observation is consistent with a transfer of hole charges from the chains to the ladders and modification of the sublattice dimensions following Ca substitution. The results are discussed in context to the significance of low lying vibrational dynamics and electron-phonon coupling in the superconducting state of certain quasiperiodic systems. (E. Constable et al., ***Physical Review B*** 100, 184305 (2019))

Anion vacancies regulating endows MoSSe with fast and stable potassium ion storage



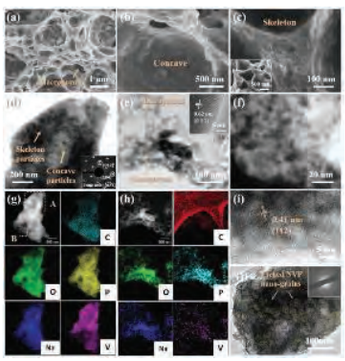
Vacancy engineering is a promising approach for optimizing the energy storage performance of transition metal dichalcogenides (TMDs) due to the unique properties of vacancies in manipulating the electronic structure and active sites. Nevertheless, achieving effective introduction of anion vacancies with adjustable vacancy concentration on a large scale is still a big challenge. Herein, $MoS_{2(1-x)}Se_{2x}$ alloys with anion vacancies introduced in situ have been achieved by a simple alloying reaction, and the vacancy concentration has been optimized through adjusting the chemical composition. Experimental and density functional theory calculation results suggest that the anion vacancies in $MoS_{2(1-x)}Se_{2x}$ alloys could enhance the electronic conductivity, induce more active sites, and alleviate structural variation in the alloys during the potassium storage process. When applied as potassium ion battery anodes, the most optimized vacancy-rich MoSSe alloy delivered high reversible capacities of 517.4 and 362.4 mAh g^{-1} at 100 and 1000 mA g^{-1}, respectively. Moreover, a reversible capacity of 220.5 mAh g^{-1} could be maintained at 2000 mA g^{-1} after 1000 cycles. This work demonstrates a practical approach to modifying the electronic and defect properties of TMDs, providing an effective strategy for constructing advanced electrode materials for battery systems. (H. He et al., ***ACS Nano*** 13, 11843 (2019))

2D Titania–carbon superlattices vertically encapsulated in 3D hollow carbon nanospheres embedded with 0D TiO_2 quantum dots for exceptional sodium-ion storage



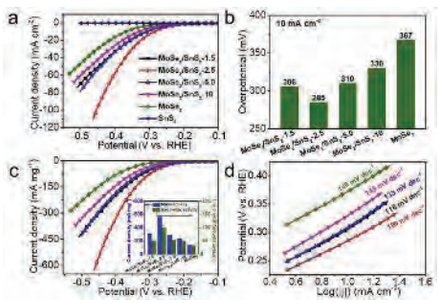
Two-dimensional (2D) superlattices offer promising technological opportunities in tuning the intercalation chemistry of metal ions. Now, well-ordered 2D superlattices of monolayer titania and carbon with tunable interlayer-spacing are synthesized by a molecularly mediated thermally induced approach. The 2D superlattices are vertically encapsulated in hollow carbon nanospheres, which are embedded with TiO_2 quantum dots, forming a 0D-2D-3D multi-dimensional architecture. The multi-dimensional architecture with the 2D superlattices encapsulated inside exhibits a near zero-strain characteristic and enriched electrochemical reactivity, achieving a highly efficient Na^+ storage performance with exceptional rate capability and superior long-term cyclability. (Q. B. Xia et al., ***Angewandte Chemie International Edition*** 58, 14125 (2019))

Organic cross-linker enabling a 3D porous skeleton–supported $Na_3V_2(PO_4)_3$/carbon composite for high power sodium-ion battery cathode



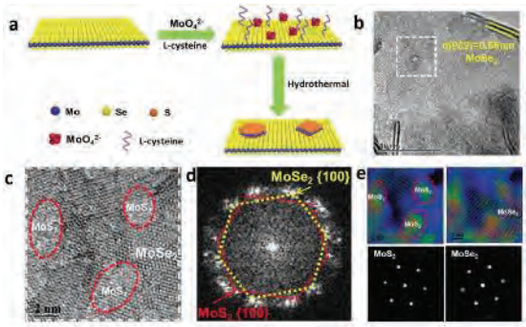
Cathodes with high energy density and good structural stability are needed for sodium-ion batteries (SIBs) to be applied in energy storage field. Herein, a 3D porous skeleton–supported $Na_3V_2(PO_4)_3$/carbon composite (NVP@C-3DPS) is synthesized via a simple sol–gel method by introducing an appropriate amount of citric acid as organic cross-linker. The generated interlinking gel provides extensive support that orients the NVP crystal growth along the ductile carbon framework, directly exposing the active material to electrolyte. Field-emission scanning electron microscopy results reveal that the hierarchical pores (macro and meso) are interconnected by the gel skeleton, with their thickness ranging from 50 to 300 nm. Thus, advantages are achieved, including a highly conductive continuous network, effective electrolyte contact surface areas, and short Na-ion transfer distance. Moreover, the cross-linking and porous property on the nanoscale gives very superior barrier-free Na-ion diffusion. Consequently, the NVP@C-3DPS electrode exhibits excellent electrochemical performance, including superior high-rate capacity (78 mA h g^{-1} at 192 C, approaching 76.9% of the initial capability of 98.6 mA h g^{-1} at 0.5 C), remarkable cycling stability (98.4% retention after 800 cycles at 1 C, 91.4% retention after 2000 cycles at 10 C), and outstanding high-rate endurance (76.0% capacity retentions after 3000 cycles at 100 C). (E. H. Wang et al., ***Small Methods*** 3, 1800169 (2019))

Electrocatalytically inactive SnS_2 promotes water adsorption/dissociation on molybdenum dichalcogenides for accelerated alkaline hydrogen evolution



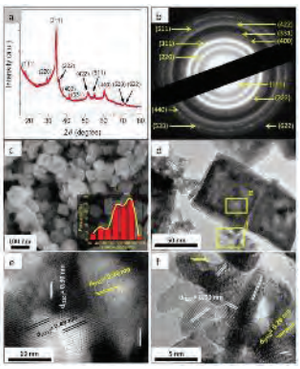
Molybdenum dichalcogenides, in particular, MoS_2 and $MoSe_2$, are very promising nonprecious metal-based electrocatalysts for hydrogen evolution reaction (HER) in acidic media. They exhibit inferior alkaline HER activity, however, due to the sluggish water dissociation process. Here, we design and synthesize new molybdenum dichalcogenide-based heterostructures with the basal planes decorated with SnS_2 quantum dots towards enhanced alkaline HER activity. The electrochemical results reveal that the alkaline hydrogen evolution kinetics of molybdenum dichalcogenides is substantially accelerated after incorporation of SnS_2 quantum dots. The optimal $MoSe_2/SnS_2$ heterostructure delivers a much lower overpotential of 285 mV than $MoSe_2$ (367 mV) to reach a current density of 10 mA cm^{-2} in 1M KOH. The improved catalytic activity is predominantly owing to the enhanced water dissociation kinetics of the heterostructures with well-defined interfaces. Density functional theory (DFT) calculations reveal that the presence of SnS_2 significantly promotes the water adsorption capability of $MoSe_2$ nanosheets, which consequently facilitates the subsequent water dissociation process. These results open up a new avenue for the rational design of well-defined heterostructures with enhanced water adsorption/dissociation capability for the development of high-performance alkaline HER electrocatalysts. (Y. P. Chen et al., ***Nano Energy*** 64, 103918 (2019))

Engineering additional edge sites on molybdenum dichalcogenides toward accelerated alkaline hydrogen evolution kinetics



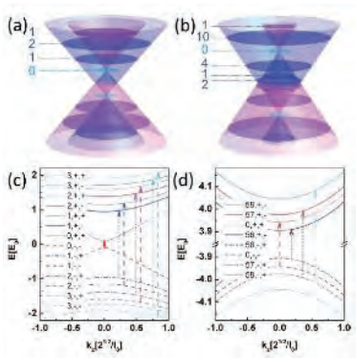
The sluggish reaction kinetics of the hydrogen evolution reaction (HER) in alkaline media is a great obstacle to alkaline water electrolysis, and it remains a great challenge to develop precious metal-free efficient catalysts for the alkaline HER. Transition metal dichalcogenides (TMDs), in particular MoS_2 and $MoSe_2$, are promising catalysts for the HER in acidic media, but they exhibit much inferior catalytic activity for the alkaline HER owing to the slow water dissociation process. In this work, we, for the first time, demonstrate that TMD heterostructures with abundant edge sites deliver substantially accelerated alkaline HER kinetics, which is in great part due to the enhanced water adsorption/dissociation capability. As a proof of concept, $MoS_2/MoSe_2$ heterostructures with ultrasmall MoS_2 nanoclusters anchored on $MoSe_2$ nanosheets are synthesized via a solution-phase process and are investigated as alkaline HER catalysts in detail. $MoSe_2$ nanosheets serve as excellent substrates to hinder the agglomeration of MoS_2 nanoclusters, resulting in abundant edge sites. Benefiting from the decent water adsorption/dissociation capability of the edge sites, the optimal $MoS_2/MoSe_2$ heterostructure shows exceptional catalytic activity in 1 M KOH with an overpotential of 235 mV at 10 mA cm^{-2} and a Tafel slope of 96 mV dec^{-1}, which is substantially improved as compared with the individual $MoSe_2$ (330 mV, 135 mV dec^{-1}) and MoS_2 (400 mV, 157 mV dec^{-1}). The success of this catalyst design strategy for enhancing alkaline HER kinetics is also demonstrated in $MoSe_2/MoSe_2$ and MoS_2/MoS_2 heterostructures. The results suggest that engineering additional edge sites that have a strong affinity for H_2O is critical for TMDs towards enhanced alkaline HER activity, and also open new avenues in the design of precious metal-free efficient catalysts for the alkaline HER. (Q. Zhou et al., ***Nanoscale*** 11, 717 (2019))

Cubic aggregates of Zn_2SnO_4 nanoparticles and their application in dyesensitized solar cells



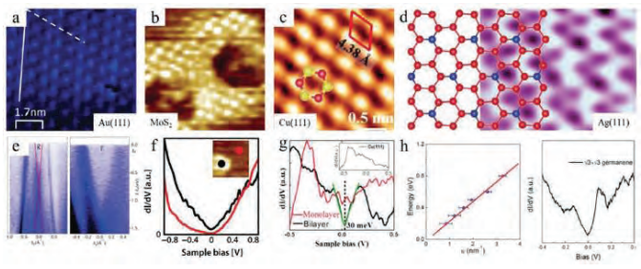
Zinc Tin Oxide (Zn_2SnO_4 or ZTO) has emerged as an alternate photoanode material for dye-sensitized solar cells (DSCs), as it offers some advantages as compared to Titania (TiO_2). In this work, crystalline ZTO nanoparticles, formed into cubic aggregate structures were synthesised by a solvothermal reaction and employed in photoanodes of DSCs, using either a high extinction coefficient organic (D149) or an organometallic (N719) dye. These were investigated in comparison with devices based on TiO_2 photoanodes, with DSCs based on ZTO|D149 showing a promising solar-to-electric conversion efficiency of 4.9%, close to that of TiO2|D149. In addition, experiments were performed using ZTO and TiO_2 in aqueous dispersions to degrade Rhodamine B, suggesting ZTO based DSCs should be more stable. Further to this, the low photocurrents seen in ZTO|N719 based devices were investigated, with the dye binding mechanism appearing to significantly impact charge injection efficiency. While the reported PCEs using this material are not as high as for the best TiO_2 based devices, the device engineering strategies outlined here provide guidelines for future development of DSCs based on this material. (K. Al-Attafi et al., ***Nano Energy*** 57, 202 (2019))

Accurate magneto-optical determination of radius of topological nodal-ring semimetals



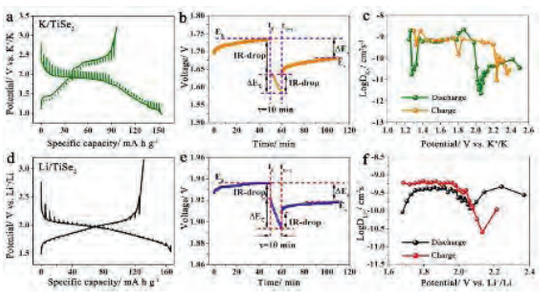
The shape of the Fermi surface of topological nodal-ring semimetals at low carrier concentrations is characterized by the ring radius $b/\hbar v_F$. This peculiar topological property may not have a clear signature in measurable physical quantities. We demonstrate an accurate and definitive method to determine the radius of topological nodal-ring semimetals. Under a magnetic field along the ring axis, the axial magneto-optical response (σ_{zz}) has a giant peak. The position of this ultrastrong response is at the frequency of exactly $2b$ and is independent of the strength of the magnetic field. The amplitude of the peak response is many times stronger than that of any other inter-Landau level transitions if the magnetic energy is greater than b and is similar strength if b is greater than the magnetic energy. The origin of the ultrastrong response is that the axial magnetic transition is governed by selection rules completely different to those governing σ_{xx} where the giant response is absent [R. Y. Chen *et al.*, Phys. Rev. Lett. **115**, 176404 (2015)]. The present work provides a method to accurately determine parameters of the topological properties of semimetals. (W. Duan et al., ***Physical Review B*** 99, 045124 (2019))

Recent progress on germanene and functionalized germanene: Preparation, characterizations, applications, and challenges



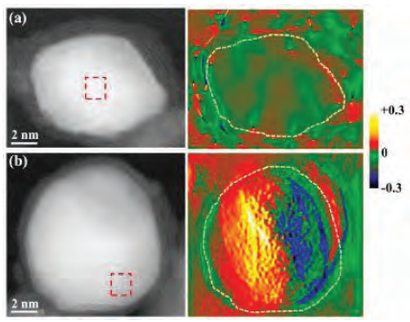
A new family of single-atom-thick 2D germanium-based materials with graphene-like atomic arrangement, germanene and functionalized germanene, has attracted intensive attention due to their large bandgap and easily tailored electronic properties. Unlike carbon atoms in graphene, germanium atoms tend to adopt mixed sp^2/sp^3 hybridization in germanene, which makes it chemically active on the surface and allows its electronic states to be easily tuned by chemical functionalization. Impressive achievements in terms of the applications in energy storage and catalysis have been reported by using germanene and functionalized germanene. Herein, the fabrication of epitaxial germanene on different metallic substrates and its unique electronic properties are summarized. Then, the preparation strategies and the fundamental properties of hydrogen-functionalized germanene (germanane or GeH) and other ligand-terminated forms of germanene are presented. Finally, the progress of their applications in energy storage and catalysis, including both experimental results and theoretical predictions, is analyzed. (N. N. Liu et al., ***Small*** 15, 1805147 (2019))

Electrochemical potassium/lithium-ion intercalation into $TiSe_2$: Kinetics and mechanism



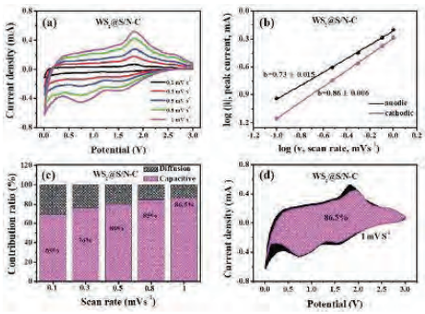
As one promising candidate for next-generation energy storage systems, K-ion batteries (KIBs) attract increasing research attention due to the element abundance, low cost, and competent energy density as compared to Li-ion batteries. However, developing practical electrode materials in particular cathodes for KIBs is still in its infancy, and the related reaction mechanisms of the electrode materials are far from completely understood. In this work, $TiSe_2$ was, for the first time, investigated as an intercalated-type electrode for potassium storage due to its large interlayer space. The potassiation/depotassiation reaction mechanism was unraveled based on the analysis of in-situ X-ray diffraction (XRD), ex-situ X-ray photoelectron spectroscopy (XPS), and ex-situ transmission electron microscope (TEM) results. Meanwhile, the lithium storage behaviour and the relevant lithiation/delithiation reaction mechanism were also studied in detail. The results reveal that K^+ show lower diffusion coefficient and hence more sluggish intercalation reaction kinetics as compared with Li^+. In addition, the intercalation reaction of K^+ would cause irreversible structure changes, while the intercalation reaction is fully reversible for Li^+ counterpart. (P. Li et al., ***Energy Storage Materials*** 16, 512 (2019))

Catalytic activity boosting of nickel sulfide toward oxygen evolution reaction via confined overdoping engineering



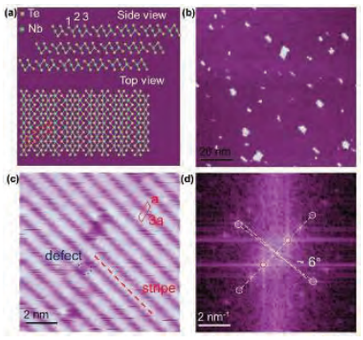
Electrocatalysis for the oxygen evolution reaction (OER) plays an irreplaceable role in numerous green and efficient energy conversion or storage techniques such as water electrolysis, fuel cells, and metal–air batteries. High-performance catalysts are always needed despite the sluggish kinetics of the four electron-transfer OER process. In this paper, for the first time, by employing a simple new strategy of "confined Fe overdoping", the OER activity of Ni_3S_2 in alkaline solution is significantly boosted, showing an overpotential of 350 mV at 10 mA cm^{-2}, which is even lower than that of the benchmark IrO_2. The designed catalyst (Meso C-NiFeS) is composed of mesoporous highly graphited N-doped carbon and nanodomain/defect/strain-rich NiFeS nanoparticles. The mesoporous carbon support facilitates mass/electron transfer, while confined Fe overdoping leads to smaller and defect/ strain-rich nanodomains. DFT calculations prove that Fe doping could induce compressing strains, which is beneficial for the OER process, modify electronic states of Ni_3S_2, and act as active sites at the same time. This overdoping strategy can trigger a synergic effect combining size decrease, electronic structure modification, and defect/strain engineering. Moreover, this simple strategy is easy to implant to other catalysts. (C. Han et al., ***ACS Applied Energy Materials*** 2, 5363 (2019))

Lotus rhizome-like S/N–C with embedded WS_2 for superior sodium storage



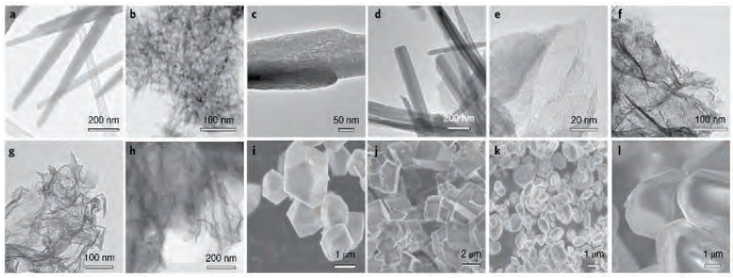
Sodium-ion batteries (SIBs) hold great promise as power sources because of their low cost and decent electrochemical behavior. Nevertheless, the poor rate performance and long-term cycling capability of anode materials in SIBs still impede their practical application in smart grids and electric vehicles. Herein, we design a delicate method to embed WS_2 nanosheets into lotus rhizome-like heteroatom-doped carbon nanofibers with abundant hierarchical tubes inside, forming WS_2@sulfur and nitrogen-doped carbon nanofibers (WS_2@S/N–C). The WS_2@S/N–C nanofibers exhibit a large discharge capacity of 381 mA h g^{-1} at 100 mA g^{-1}, excellent rate capacity of 108 mA h g^{-1} at 30 A g^{-1}, and a superior capacity of 175 mA h g^{-1} at 5 A g^{-1} after 1000 cycles. The excellent performance of WS_2@S/N–C is ascribed to the synergistic effects of WS_2 nanosheets, contributing to larger interlayer spacing, and the stable lotus rhizome-like S/N–C nanofiber frameworks which alleviate the mechanical stress. Moreover, the WS_2@S/ N–C electrode shows obvious pseudocapacitive properties at 1 mV s^{-1} with a capacitive contribution of 86.5%. In addition, density functional theory calculations further indicate that the WS_2@S/N–C electrode is very favorable for Na storage. This novel synthetic strategy is a promising method for synthesizing other electrode materials for rechargeable batteries in the future. (X. Li et al., ***Journal of Materials Chemistry A*** 7, 25932 (2019))

Role of charge density wave in monatomic assembly in transition metal dichalcogenides



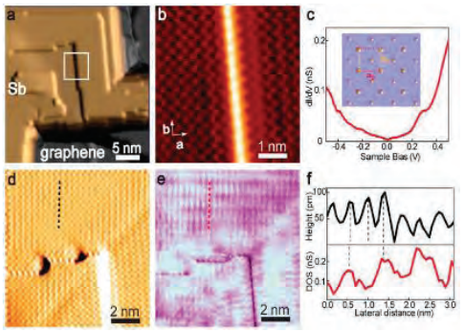
The charge density wave (CDW) in transition metal dichalcogenides (TMDs) has drawn tremendous interest due to its potential for tailoring their surface electronic and chemical properties. Due to technical challenges, however, how the CDW could modulate the chemical behavior of TMDs is still not clear. Here, this work presents a study of applying the CDW of $NbTe_2$, with a high transition temperature above room temperature, to generate the assembling adsorption of Sn adatoms on the surface. It is shown that highly ordered monatomic Sn adatoms with a quasi-1D structure can be obtained under regulation by the single-axis CDW of the substrate. In addition, the CDW modulated superlattices could in turn change the surface electronic properties from semimetallic to metallic. These results demonstrate an effective approach for tuning the surface chemical properties of TMDs by their CDWs, which could be applied in exploring them for various practical applications, such as heterogeneous catalysis, epitaxial growth of low-dimensional materials, and future nanoelectronics. (H. F. Feng et al., ***Advanced Functional Materials*** 29, 1900367 (2019))

Morphology tuning of inorganic nanomaterials grown by precipitation through control of electrolytic dissociation and supersaturation



The precise control of the morphology of inorganic materials during their synthesis is important yet challenging. Here we report that the morphology of a wide range of inorganic materials, grown by rapid precipitation from a metal cation solution, can be tuned during their crystallization from one- to three-dimensional (1D to 3D) structures without the need for capping agents or templates. This control is achieved by adjusting the balance between the electrolytic dissociation (α) of the reactants and the supersaturation (S) of the solutions. Low-α, weak electrolytes promoted the growth of anisotropic (1D and 2D) samples, with 1D materials favoured in particular at low S. In contrast, isotropic 3D polyhedral structures could only be prepared in the presence of strong electrolyte reactants ($\alpha \approx 1$) with low S. Using this strategy, a wide range of materials were prepared, including metal oxides, hydroxides, carbonates, molybdates, oxalates, phosphates, fluorides and iodate with a variety of morphologies. (W. H. Lai et al., ***Nature Chemistry*** 11, 695 (2019))

Possible excitonic insulating phase in quantum-confined Sb nanoflakes



In the 1960s, it was proposed that in small indirect band-gap materials, excitons can spontaneously form because the density of carriers is too low to screen the attractive Coulomb interaction between electrons and holes. The result is a novel strongly interacting insulating phase known as an excitonic insulator. Here we employ scanning tunnelling microscopy (STM) and spectroscopy (STS) to show that the enhanced Coulomb interaction in quantumconfined elemental Sb nanoflakes drives the system to the excitonic insulator state. The unique feature of the excitonic insulator, a charge density wave (CDW) without periodic lattice distortion, is directly observed. Furthermore, STS shows a gap induced by the CDW near the Fermi surface. Our observations suggest that the Sb(110) nanoflake is an excitonic insulator. (Z. Li et al., ***Nano Letters*** 19, 1960 (2019))

Selected Publications

In 2019 ISEM published 2 articles in Science, 5 in Nature group journals, 9 in Advanced Materials, 15 in Advanced Energy Materials, 16 in Energy Storage Materials, and 14 in Angewandte Chemie International Edition. Overall ISEM published 185 articles in journals with impact factor above 10, which constitutes 44.36% of publications.

1. K. Al-Attafi, F. H. Jawdat, H. Qutaish, P. Hayes, A. Al-Keisy, K. Shim, Y. Yamauchi, S. X. Dou, A. Nattestad, and J. H. Kim, "Cubic aggregates of Zn_2SnO_4 nanoparticles and their application in dye-sensitized solar cells", ***Nano Energy* 57**, 202 (2019). [IF: 15.548]

2. K. Bogusz, M. Zuchora, V. Sencadas, M. Tehei, M. Lerch, N. Thorpe, A. Rosenfeld, S. X. Dou, H. K. Liu, and K. Konstantinov, "Synthesis of methotrexate-loaded tantalum pentoxide-poly(acrylic acid) nanoparticles for controlled drug release applications", ***Journal of Colloid and Interface Science* 538**, 286 (2019). [IF: 7.489]

3. L. Chen, J. Zuber, Z. S. Ma, and C. Zhang, "Nonlinear optical response of the alpha-T-3 model due to the nontrivial topology of the band dispersion", ***Physical Review B* 100** (3) (2019). [IF: 3.575]

4. M. Z. Chen, Q. N. Liu, S. W. Wang, E. H. Wang, X. D. Guo, and S. L. Chou, "High-abundance and low-cost metal-based cathode materials for sodium-ion batteries: problems, progress, and key technologies", ***Advanced Energy Materials* 9** (14), 1803609 (2019). [IF: 24.884]

5. M. Z. Chen, W. B. Hua, J. Xiao, D. Cortiel, W. H. Chen, E. H. Wang, Z. Hul, Q. F. Gu, X. L. Wangl, S. Indris, S. L. Chou, and S. X. Dou, "NASICON-type air-stable and all-climate cathode for sodium-ion batteries with low cost and high-power density", ***Nature Communications* 10,** 1480 (2019). [IF: 11.878]

6. Y. P. Chen, X. Y. Wang, M. M. Lao, K. Rui, X. B. Zheng, H. B. Yu, J. Ma, S. X. Dou, and W. P. Sun, "Electrocatalytically inactive SnS_2 promotes water adsorption/dissociation on molybdenum dichalcogenides for accelerated alkaline hydrogen evolution", ***Nano Energy* 64**, 103918 (2019). [IF: 15.548]

7. S. K. Chong, L. Sun, C. Y. Shu, S. W. Guo, Y. N. Liu, W. Wang, and H. K. Liu, "Chemical bonding boosts nano-rose-like MoS_2 anchored on reduced graphene oxide for superior potassium-ion storage", ***Nano Energy* 63**, 103868 (2019). [IF: 15.548]

8. E. Constable, A. D. Squires, J. Horvat, R. A. Lewis, D. Appadoo, R. Plathe, P. Roy, J. B. Brubach, S. deBrion, A. Pimenov, and G. Deng, "Effects of Ca substitution on quasiacoustic sliding modes in $Sr_{14-x}Ca_xCu_{24}O_{41}$", ***Physical Review B* 100** (18), 184305 (2019). [IF: 3.575]

9. J. Cuan, Y. Zhou, T. F. Zhou, S. G. Ling, K. Rui, Z. P. Guo, H. K. Liu, and X. B. Yu, "Borohydride-scaffolded Li/Na/Mg fast ionic conductors for promising solid-state electrolytes", ***Advanced Materials* 31** (1), 1803533 (2019). [IF: 25.809]

10. J. Cuan, Y. Zhou, J. Zhang, T. F. Zhou, G. M. Liang, S. A. Li, X. B. Yu, W. K. Pang, and Z. P. Guo, "Multiple anionic transition-metal oxycarbide for better lithium storage and facilitated multielectron reactions", ***ACS Nano* 13** (10), 11665 (2019). [IF: 13.903]

11. W. Dong, D. Cortie, T. Lu, Q. B. Sun, N. Narayanan, W. B. Hu, L. Jacob, Q. Li, D. H. Yu, H. Chen, A. P. Chen, X. Y. Wei, G. M. Wang, M. G. Humphrey, T. J. Frankcombe, and Y. Liu, "Collective nonlinear electric polarization via defect-driven local symmetry breaking", ***Materials Horizons* 6** (8), 1717 (2019). [IF: 14.356]

12. W. Y. Duan, C. H. Yang, Z. S. Ma, Y. M. Zhu, and C. Zhang, "Accurate magneto-optical determination of radius of topological nodal-ring semimetals", ***Physical Review B* 99** (4), 045124 (2019). [IF: 3.575]

13. M. H. Fang, T. H. Yang, T. Lesniewski, C. Lee, S. Mahlik, M. Grinberg, V. K. Peterson, C. Didier, W. K. Pang, C. C. Su, and R. S. Liu, "Hydrogen-Containing $Na_3HTi_{1-x}Mn_xF_8$ narrow-band phosphor for light-emitting diodes", ***ACS Energy Letters* 4** (2), 527 (2019). [IF: 16.331]

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Funding 2019

AUSTRALIAN RESEARCH COUNCIL GRANTS

ARC CENTRE OF EXCELLENCE

Chief Investigators	Title	2019 Funding
X. L. Wang via M. Fuhrer et al.	ARC Centre of Excellence in Future Low Energy Electronics Technologies	$219,000
Total		$219,000

ARC DISCOVERY SCHEME GRANTS

Chief Investigators	Title	2019 Funding
S. X. Dou, Z. Q. Sun, X. Xu, T. Liao, Z. F. liu, H. Zhang, J.-B. Baek, L. M. Dai	Multifunctional 2D materials for sustainable energy applications	$154,000
Z. G. Huang, H. K. Liu, H. B. Yu, X. B. Yu	Liquid phase hydrogen carriers for energy storage and delivery	$130,000
X. L. Wang, Z. Li, Z. X. Cheng, Y. Du	Atomically thin superconductors	$124,000
S. X. Dou, Y. Du, X. Xu, G. Peleckis, J. H. Ye, W. X. Hao, L. Chen	Two-dimensional plasmonic heterogeneous nanostructures for photocatalysis	$171,000
Z. P. Guo, K. Konstantinov, X. W. Lou, Z. Zhou	Potassium ion batteries for large scale renewable energy storage	$164,000
J. Z. Wang, K. Konstantinov, W. S. Yang, Q. F. Gu	Development of ambient air operation rechargeable sodium-air batteries	$124,000
Z. X. Cheng, X. L. Wang, W. H. Wang, H. X. Yang, E. Gilbert	Magnetic skyrmion materials for next generation spintronic-based devices	$137,000
Total		$1,004,000

ARC FUTURE FELLOWSHIPS

Chief Investigators	Title	2019 Funding
Z. P. Guo	Exploration of advanced nanostructures for sodium-ion battery application	$117,000
W. K. Pang	High-voltage electrode materials for lithium-ion batteries	$163,000
Y. Du	Functional two-dimensional materials for photocatalysis	$219,000
Total		$499,000

ARC DECRA FELLOWSHIPS		
Chief Investigators	Title	2019 Funding
J. Liang	Carbon-based catalysts for polysulphide redox reactions in lithium-silicon batteries	$120,000
C. Wu	Electrode materials for sodium storage	$120,000
Y. X. Wang	Room-temperature sodium sulphur batteries	$120,000
G. L. Xia	Nanostructure metal hydrides for practical hydrogen storage applications	$120,000
D. Cortie	Engineering magnetism at the atomic scale in topological insulators	$118,000
F. Li	High performance lead-free piezoelectrics based on polar nanoregions	$120,000
W. J. Li	Long life sodium ion batteries by optimising initial coulombic efficiency	$118,000
T. F. Zhou	Interphases and interfaces of nanomaterials in potassium-ion batteries	$128,000
Z. Li	Engineering of exotic electronic properties in atomically thin antimony	$120,000
Y. Lu	Nanostructures derived from metal-organic frameworks for sodium-ion batteries	$136,000
Total		$1,220,000

ARC LINKAGE PROJECTS		
Chief Investigators	Title	2019 Funding
S. X. Dou, W. P. Sun, K. W. See, X. Xu	Development of the next generation battery storage system for smart grid	$140,000
J. Z. Wang, H. K. Liu, K. Konstantinov, S. L. Chou	Development of novel safe lithium metal-free sulfur batteries	$45,000
M. S. A. Hossain, S. X. Dou, J. H. Kim, Y. Yamauchi, R. Taylor, V. Luzin, A. Devred	Nanostructure engineered low activation superconductors for fusion energy	$109,000
Z. P. Guo, J. F. Mao, W. Li	High energy density, long life, safe lithium ion battery for electric cars	$119,000
S. X. Dou, X. Xu, Y. Du, W. P. Sun, K. W. See, J. Zheng	Liquid metal for quench detection sensors and low resistance joints	$97,000
Total		$510,000
2019 Australian Research Council Grants Total:		$3,452,000

ARENA PROJECT		
Chief Investigators	Title	2019 Funding
S. X. Dou, H. K. Liu, S. L. Chou, K. W. See	The Smart Sodium Storage Solution (S4)	$1,182,000
2019 ARENA Project Total:		$1,182,000

UOW GRANTS		
Chief Investigators	Title	2019 Funding
G. Peleckis	X-ray Photoelectron Spectroscopy (XPS) System	$980,000
J. Knott	Innovative organogels for low-cost sodium-ion battery separators	$7,500
W. P. Sun	Exploring the possible roles of g-C_3N_4 in electrocatalysis applications	$7,000
Total		$994,500
UOW support	Performance, Management, PGS Maintenance	$500,000
Total Funding 2019		$6,128,500

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