ISEM 2022 performance and outcomes highlights

2022 On-going projects:

1. SCOPING THE WORLD OF ULTRA-THIN FILM AND ULTRA-HIGH PRESSURE ENVIRONMENTS

Total Funding: $521,816.00

Project ID: LE220100085
Lead CI: X.L. Wang

Partner Investigators: Germanas Peleckis, Roger Lewis, Ajayan Vinu, Tom Wu, L.Wang, J. Z.W, Z.J, Yue, F.X. Xiang, G.L. Zheng, Q.W.Wang.

Project Summary: This proposal will establish a unique Australian research facility, a combination of high efficiency Thin Film Thermophysical Property Analyser and a complete package of tools for materials and devices fabrication and characterisation at ultra-high pressures Almax DiaCell. This exceptionally comprehensive and versatile set of tools will foster collaborative activities between participating research organisations supporting breakthrough research conducted by more than 30 researchers across more than 20 ARC and other projects to discover novel unconventional phenomena in topological insulators, superconductors, spintronic materials, low energy devices, one- and two-dimensional micro- and nano-materials, battery, and bio-magnetic materials.

2. FUNCTIONAL TOPOLOGICAL MATERIALS FOR SUPERIOR THERMOELECTRIC APPLICATIONS

Total Funding: $411,433.00

Project ID: LP200201096
Lead CI: X.L. Wang

Partner Investigators: Z.J. Yue, David Cortie

Project Summary: The efficient generation of electricity from waste heat remains a significant technological challenge, hampered by the absence of efficient materials for conversion. This project aims to develop functionalized topological materials with ultra-high thermoelectric and photothermal performance for harvesting heat into electricity. A recent breakthrough in device efficiency will be a game-changer and position Australian academics and industries at the forefront of next generation of renewable power generation and refrigeration products. The outcomes will provide an advantage to end-users and industry, and will open a new market for advanced thermoelectric devices in multidisciplinary fields, communities and emerging industries.

3. SODIUM-METAL-FREE, SAFE AND SUSTAINABLE SODIUM-ION SULFUR BATTERIES

Total Funding: $393,531.00

Project ID: DP220103301
Lead CI: S.L. Chou

Partner Investigators: Y.X. Wang, J.Z. Wang, Yong Mook Kang.

Project Summary: This project aims to develop sodium sulfide cathodes via effective single-atom catalysts and elaborately regulate the solid-electrolyte interphase on the anode by using a new class of electrolytes. Thus, the obtained low-cost, high-energy, safe sodium-ion sulfur batteries can serve as a novel technique for largescale stationary energy storage, especially for intermittent solar and wind energy storage in Australia. Expected outcomes include a comprehensive understanding and a breakthrough in advances of innovative and affordable battery storage technology, leading to significant scientific, economic, environmental, and social benefits to Australia by integrating this battery system with renewable energy

4. BEYOND THE FERROELECTRIC FIELD EFFECT TRANSISTORS

Total Funding: $514,618.00

Project ID: DP220103229
Lead CI: Sean Li (The University of New South Wales)

UOW CI: S.J. Zhang

Project Summary: The von Neumann paradigm is the foundation of modern computing systems, which are based on the data exchange between central processing unit (CPU) and memory. The physical separation between the CPU and memory will cause von Neumann bottleneck – a memory wall to limit the data processing speed for contextually intelligent applications. This project aims to develop a novel ferroelectric field effect transistor that integrates a ferroelectric material into a semiconductor transistor structure to merge logic and memory functionalities in a single-device level. This will solve the memory wall problem while provide low power, high speed, high density and long data retention time for future logic-in-memory and data centric computing paradigms.

5. 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.

6. Sodium-Ion battery pack for explosion proof electric vehicle

Years Funded: 2021 2022 2023
$300,000 $300,000 $300,000

Total Funding: $900,000

Project ID: IH200100035
Lead CI: Ian Chen (Deakin University)

UOW CI: K.W. See, C. Cook, H.K. Liu, J.C. Knott

Project Summary: This Research Hub addresses safety and reliability issues, and environmental impact of current energy storage and conversion technologies. The research will deliver a new generation of technologies for
storage from small scale portable devices to large scale industrial applications, using recycled and natural materials, and eliminating the serious fire risk in current technologies. Outcomes include innovative integrated energy conversion and storage technologies and new energy materials and devices designed for different scale applications, leading to creation of start up companies and commercialisation opportunities for existing partners, benefiting both the Australian economy and potentially transforming the energy industry landscape.

7. Carbon-free Energy Storage and Conversion Using Ammonia as a Mediator.

Years Funded: 2021 2022 2023
$191,270 $191,259 $191,259

Total Funding: $573,788

Project ID: DP210102215
Lead CI: S. X. Dou

Partner Investigators: J. Liang, W. J. Li

Project Summary: This project aims to develop essential technologies for ammonia-mediated energy storage, hydrogen production, and electricity generation. This project expects to generate new understandings on designing novel multi-atom-cluster catalysts for the critical ammonia synthesis, electrolysis, and oxidation processes using interdisciplinary approaches. The expected outcomes of this project include multi-functional electrocatalysts, fundamental insights of principles for electrocatalyst design, and prototype technologies. This should provide significant benefits for the harvest of clean energy, the safe utilization of hydrogen, and the development of carbon-free fuels, which are essential for optimizing the energy structure of Australia.

8. Hot Topic: Quantum Design of Phononic Heat Filters.

Years Funded: 2021 2022 2023
$105,000 $105,000 $105,000

Total Funding: $315,000

Project ID: DP210101436
Lead CI: D. A. Cortie

Partner Investigators: Z.J. Yue, Z.X. Cheng, R.A. Lewis, C. Zhang

Project Summary: Heat management is critical to many technologies for sustainable energy, electronics, protective equipment, and energy-efficient buildings. The phonon is the quantum particle representing a travelling vibration and is responsible for the transmission of heat in solids. This project will study the new mechanisms for phonon transport in solids modified with embedded nanoparticles, which operate as phononic filters. Neutron spectroscopy provides a tool to measure the phonon density of states which is critical for developing a mathematical model of thermal boundary resistance. This is expected to identify mechanisms for ultra-low thermal conductivity leading to potential applications in thermoelectric generators and heat-resistant materials.

9. Controlling and understanding interface chemistry for energy conversions

Years Funded: 2020 2021 2022
$160,000 $160,000 $160,000

Total Funding: $480,000

Project ID: DP200100365
Lead CIs: S. X. Dou, W. P. Sun, J. Liang

Partner Investigators: Y. Y. Liu, C. Z. Wu, J. B. Baek

Project Summary: This project aims to develop a promising electrocatalyst technology platform, based on novel 2D material architectures that have applications ranging from hydrogen generation via water splitting through to carbon dioxide reduction. The project is expected to generate advanced knowledge for the rational design of electrocatalysts and to promote the development of renewable energy technologies. Expected outcomes include a clear understanding of the relevant fundamental science and mechanisms, a framework for designing and optimising for specific applications, and a demonstration of prototype devices. This project is of great benefit for addressing Australia’s energy and environmental concerns and boosting national economic growth as well.

10. Exploration of lead free ferroelectric crystals for transducer applications.

Years Funded: 2019 2020 2021 2022
$64,680.25 $64,680.25 $64,680.25 $64,680.25

Total Funding: $258,721

Project ID: LP170100713
Lead CIs: S.J. Zhang, Z.X. Cheng

Partner Investigators: Val.Kurusingal,Chr.Dean,etc.

Project Summary: This project aims to investigate lead free crystals, which are expected to possess high piezoelectric properties for medical imaging and underwater acoustics, as an alternative to toxic lead-based ferroelectrics which have been dominantly used in ultrasound transducers. The project will have significant impact on development of new lead-free ferroelectric crystals with desirable properties. This will benefit Australian industry by providing knowledge and technology of crystal growth, enabling advanced ultrasound transducers for medical imaging and underwater acoustic applications.

11. IoT-Battery Electric Transporter for Underground Coal Mining

Year Funded: 2019 2020 2021 2022
$320,000 $300,000 $200,000 $100,000

Total Funding: $920,000

Project ID: GILII000002
Lead CI: See Khay W

Project Summary: The project proposed is a comprehensive investigation and development which will remove current barriers to use electrification to allow operation of diesel-free general purpose vehicles in complex, difficult and challenging conditions such as underground mining environments. This project will pave the way to replace diesel in heavy duty underground vehicles. The scope of the project is a fully approved and accredited battery electric transporter with IoT technology incorporated for underground coal applications in Australia. This vehicle is heavily employed as a transportation machine in underground coal for mine workers and visitors and could also convertible where seating for personnel could be folded away leaving the vehicle suitable for materials.

12. Economical electrode materials for safe sodium ion batteries

Years Funded: 2020 2021 2022
$138,000 $137,000 $137,000

Total Funding: $412,000

Project ID: DE200101384
Chief Investigator: N. N. Wang

Project Summary: The project aims to address the lack of effective anode materials for high performance sodium-ion batteries, through the development of functional titanium-based materials, realizing high energy/power density, long cycle life, low cost and high safety sodium ion batteries. Expected outcomes of this project will address the limitation of current energy storage technologies and be beneficial for the development of large-scale energy storage systems that are efficient, cost-effective and reliable in Australia. This project will explore titanium-based materials with advantageous architectures and deeply doped heteroatoms by novel synthetic strategies and will be assessed as electrode materials for high performance batteries.

13. Liquid metal for quench detection sensors and low resistance joints

Years Funded: 2019 2020 2021 2022
$47,000 $90,000 $83,000 $42,000
Industry Fund: $50,000 $50,000 $50,000

Total Funding: $412,000

Project ID: LP180100722
Lead CIs: 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.

14. The impact of A-Site dopant on the electromechanical properties of relaxor-PT material system.

Years Funded: 2021 2022 2023
$145,500 $145,500 $145,000

Total Funding: $436,000

Project ID: N62909-21-1-2037
Lead CI: S.J.Zhang

Project Summary: This project is to study the relationship between local structure including the oxygen octahedral in the perovskite materials and macroscopic piezoelectric properties.

15. Crystal growth of large size relaxor-PT ferroelectric single crystals

Years Funded: 2021 2022 2023 2024
$707,500 $707,500 $200,000 $200,000

Total Funding: $1,815,000

Project ID: 9.140
Lead CI: S.J.Zhang

Project Summary: This project is to study the crystal growth of large size ferroelectric single crystals for ultrasound transducer applications.

HDR completions:

2022 has seen 9 **PhD student completions.** Our HDR students graduated with high standards and many of them have been sought-after by academia and industry. They have been absorbed into very reputable profession in their home countries or other countries, and some of them have stayed at ISEM and continued to make contributions to UOW. This year we had also a record number of new successful HDR students, who received UoW scholarships – more than 10.

Publications:

Despite the departure of many senior or high-profile staff in 2022, ISEM has published ***250+ high-impact papers***, with many of them jointly authored with our collaborators globally. It is worth noting that many publications have appeared in top journals, such *as Science (2), Nature Materials (1), Nature Review Physics(1), Science Advances (2), Nature Communications (3), and many other high-impact journals such as Advanced Materials, PNAS, EES, etc.* Many thanks to Distinguished Prof. Shujun Zhang, who contributed to 6 of these Nature and Science series papers.

Successful funding applications:

This year ISEM has yet again been successful in attracting competitive grants from different funding organisations, such as the ARC, the federal government, various companies, domestic or international consulting and research contracts, etc. Congratulations to the following ISEM staff on their successful grant applications:

1. ISEM won **two ARC DPs** (over $815,000 in total): led by A/Prof Wei Kong Pang and Prof. Xiaolin Wang, and

DP230100198, A/Prof. Wei Kong Pang, Dr. Xun Xu, A/Prof. Khay See, and Dr. Bernt Johannessen "Enabling high-performance layered oxide sodium-ion battery cathodes"

DP230102221, Prof. Xiaolin Wang, Prof. Chao Zhang, Dr. Zhi Li, and Dr. Kirrily Rule, "Giant Magnetic-thermoelectricity in topological materials"

2. One Defence Materials Technology Centre (DMTC) funding ($1.8M) led by Prof. Shujun Zhang

3. One Korean government funding ($120K+)

Prof. Jung Ho Kim, is a lead CI on a sub-project on "Groundbreaking research on MgB2 superconducting joints for various magnet systems", funded by the Ministry of Science and ICT, Republic of Korea. Total budget for 4.5 years is KRW 240,000,000 (around AUD 260,000). Partnership with the Seoul National University.

4. One UOW-ANSTO seed grant led by Dr Nana Wang:

Dr Nana Wang, PhD student, Mingyue Wang: ANSTO-UOW 2022 seed funding - $15,563.70 'Understanding the effects of doped heteroatoms at the atomic level for titanium based materials'

5. One joint LIEF application led by ANU:

LE230100024, A cryogenic multifunctional multiscale material characterisation facility ISEM CIs: Prof Zhenxiang Cheng and Shujun Zhang

6. Please join me in congratulating Drs Xun XU, Yunxiao Wang, and Weihong Lai for winning three 2022 UOW AEGiS grants (The UOW Advancement and Equity Grants Scheme for Research).

Lead Chief Investigator: Dr Xun Xu
Project Title: Magnetic-field-induced liquid metal scaffold/surface for regulation of microneedle
UOW Funding Awarded $19,755

Lead Chief Investigator: Dr Yun-Xiao Wang
Project Title: Capturing CO2 as advanced cathodes for a green and low-cost sodium storage system
UOW Funding Awarded $19,340

Lead Chief Investigator Dr Weihong Lai
Project Title Ammonification of plastic wastes to universally synthesize single-atom catalysts for hydrogen production
UOW Funding Awarded $16,000

7. ISEM has also secured the ARC Research Hub (led by A/Prof Khay) which is part of the SafeREnergy Hub led by the Deakin University.

ISEM has 5 Clarivate 2022 Highly Cited Researchers:

- Distinguished Professor Shujun Zhang – Cross Field
- Distinguished Emeritus Professor Hua Kun Liu – Materials Science
- Distinguished Emeritus Professor Shi Xue Dou – Chemistry
- Distinguished Emeritus Professor Shi Xue Dou – Materials Science
- Honorary Distinguished Professor Yoshio Bando – Materials Science

Awards and recognition:

1. Warmest congratulations to Distinguished Prof Hua kun Liu for being honoured as a Member of the Order of Australia (AM) in the general division for significant service to the scientific research sector and tertiary education.

2. Distinguished Professor Shixue Dou and Distinguished Professor Huakun Liu were admitted as *Emeritus Professors* to the *University of Wollongong* (*UOW*)

3. Distinguished Prof. Hua Kun Liu is ranked No. 6 Top Female Scientist in Australia for 2022.

4. Distinguished Professor Shi Xue Dou and Dis. Prof Shujun Zhang were named as the top researchers the fields of electrochemistry; materials engineering; nanotechnology and ceramic engineering).

Joint MMMB and ISEM new teaching initiatives

In conjunction with MMMB, Prof. Kosta Konstantinov and Prof. Zhenxiang Cheng have established new subjects MATE415 and MATL912 – Advanced Energy Materials, which will be hosted at ISEM and will create teaching opportunities for prospective ISEM ECR researchers. This initiative provides seamless integration of the teaching process with the high-class research performed at ISEM in the field of energy storage materials, and it will reflect in increased number of UoW students seeking future HDR positions at UoW.