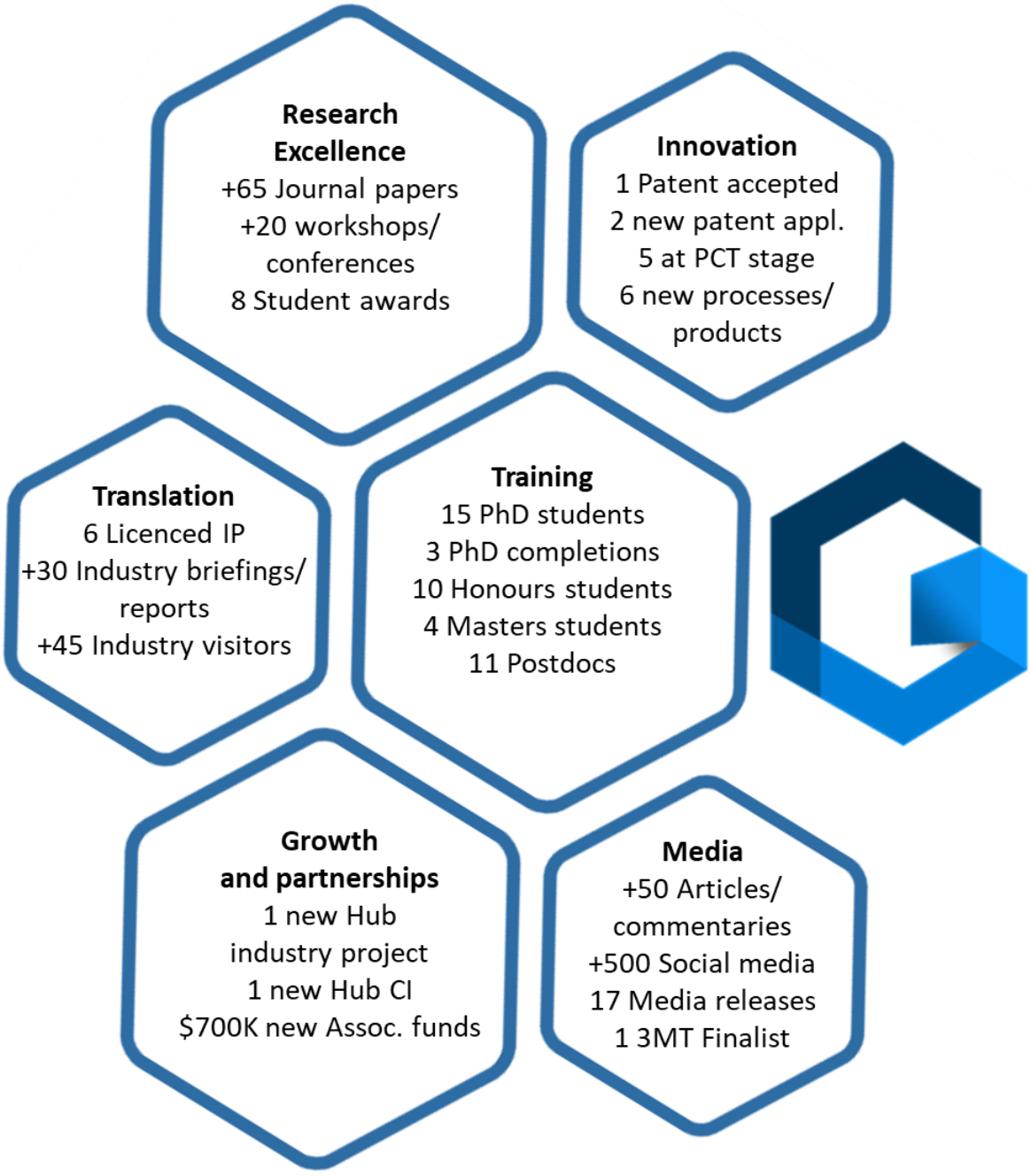
The ARC Research Hub for
GRAPHENE
ENABLED
INDUSTRY
TRANSFORMATION

ARC GRAPHENE RESEARCH HUB

Annual Report 2020

2020 HIGHLIGHTS SUMMARY



FORWARD FROM THE HUB DIRECTOR

The ARC Graphene Research Hub has completed our third year and we are delighted to present our research progress and outcomes from 2020.

In this year under most difficult challenges and interruptions caused by the Covid-19 pandemic our Hub teams across all Universities we made enormous efforts to continue making a substantial scientific progress on translation of graphene research and delivery of new discoveries, innovation and outcomes to our industry partners.

During most critical lock-down time last year when our Universities were closed most of our teams continue to with research activities work to deliver committed work producing many astonishing results. This year was even more productive then previous in terms of the number of papers published and still manage to participate in many virtual conferences, workshops presentations, create new IP, develop new products and advanced their technical readiness. The most outstanding examples are graphene fire retardants, sulphur-Li-ion batteries, corrosion protective coatings, membranes and adsorbents for water purification, graphene polymer composites, sensors etc.

The ARC Graphene Hub continues to have a visible international reputation during the pandemic with organizing of the Australian-European Graphene workshop and connection with the European Union Graphene Flagship, participation in the ISO standardization on graphene and Versailles Project on Advanced Materials and Standards (VAMAS) program leading one of the International Interlaboratory Comparison (ILC) projects. These activities make a notable impact and contribution to global graphene research and commercialization, improving existing and fostering new international collaborations with Australian researchers and Australian graphene companies.

Finally, I would like to thank the ARC, our industry partners, the universities for their support, the Hub Management, research teams, and most gratefully to our postdoctoral researchers and PhD students for their enthusiastic and tireless lab work.

Professor Dusan Losic

ARC Hub Director

Adelaide, March 2021

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ACKNOWLEDGEMENTS

The ARC Graphene Research Hub would like to acknowledge the Australian Research Council for core funding and the generous financial and in-kind support from our Industry Partners, First Graphene, Archer, Cleanfuture Energy, NematiQ, and Sparc Technologies. We would also like to thank The Institute of Mining and Energy Resources (IMER) for their ongoing financial support and all our university collaborators: Monash University, RMIT University, The University of Melbourne, University of South Australia, Queensland University of Technology and The University of Adelaide.

ARC Graphene Research Hub

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1. EXECUTIVE SUMMARY

- The Hub's research operation in 2020 across all 6 universities and 5 industry partners have been interrupted during the COVID-19 pandemic lock-down restrictions and travel limitation, but all committed outcomes and deliverables were completed as projected.
- The Hub Management team implemented online communication systems and, thanks to the university support, the impact on research activities was minimized giving our researchers and student chances to work in labs during pandemic.
- This year was a most productive year in terms of research publication with +65 published journal papers, most in very high impact journals, attracting new research funding, innovations, extensive research translation, media releases and research training.
- The Hub's industry partners also continued to grow this year and further improve and develop their business operations including their international partnerships to become world leaders in the emerging graphene industry.
- In March we held the second Hub Workshop in Melbourne, at Monash University with +60 participants with great success in presenting Hub research activities across different groups, universities and our Industry partners, associated partners and research organizations (CSIRO).
- Early in 2020 many team members also attended the Australian premier of the Nanotechnology ICONN conference in person with a significant contribution (4 oral and 3 poster presentations) and the Hub team came together for the annual workshop prior to pandemic.
- We managed to keep our ongoing international collaborations with European Union Graphene Flagship, ISO standardization and VAMAS program by online connections.
- The Hub continued to successful train HDR students with completion of 3 PhD, 5 Masters and 10 Honours students with many awards.

2. HUB OVERVIEW

The ARC Graphene Enabled Industry Transformation Research Hub

The Graphene Hub is a partnership between 6 Australian universities and 5 industry partners jointly funded by the Australian Research Council.

The Hub aims to develop a sustainable graphene-based industry in Australia with products that can address many industry, medical and environmental challenges.

Graphene is a 2-dimensional (2D) material with exceptional properties. Translating graphene research into reliable products and solutions has several challenges that will be addressed by research teams:

- Scalable, low-cost, sustainable graphene manufacturing process and supply chain
- Implement graphene quality control and international standards
- Ensure graphene materials are safe for use.

Vision

To be a world-leader in translation and commercialisation of graphene research that will deliver new discoveries, innovative technologies, products and devices to industry partners and impact industry transformation to drive growth across a range of industries providing social, economic and environmental benefits.

Values

Imagination, Innovation, Excellence, Diversity, Passion, Delivery, Teamwork

Mission

- To create new products and technologies to promote industry transformation using graphene materials and technologies
- To translate this knowledge for our partners for graphene-enabled commercialisation
- To promote graphene industries using Australia's graphite mining resources

RESEARCH AND MANAGEMENT TEAMS

Directors

Prof Dusan Losic
University of Adelaide

Prof Mainak Majumder
Monash University

Prof Stan Skafidis
University of Melbourne

Hub Manager

Dr Jacqui McRae
University of Adelaide

Chief Investigators

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RMIT

Prof Christophe Fumeaux
University of Adelaide

Prof Jun Ma
University of South Australia

Prof Reza Ghomashchi
University of Adelaide

Prof Michael McLaughlin
University of Adelaide

A/Prof Deepak Dubal
QUT

Partner Investigators

Craig McGuckin
First Graphene

Mohammad Choucair
Archer Materials

Uli Krueger
Cleanfuture Energy

Peter Voigt
NematiQ

Stephen Hunt
Graphene Technology Solutions

Postdoctoral Researchers


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Dr Tanesh Gamot
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Mr Joynul Abedin
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Mr Tuan Sang Tran
RMIT


Ms Le Yu
University of Adelaide


Mr Tianzhi Li
University of Melbourne


Mr Sadeq Zafarini
University of Adelaide


Mr Petar Jovanovic
Monash University


Ms Pei Lay Yap
University of Adelaide


Mr Kamrul Hassan
University of Adelaide


Mr Hadi Rastin
University of Adelaide


Mr Arash Mazinani
University of Adelaide


Mr Mathais Aakyiir
UniSA

GOVERNANCE AND COMMITTEES

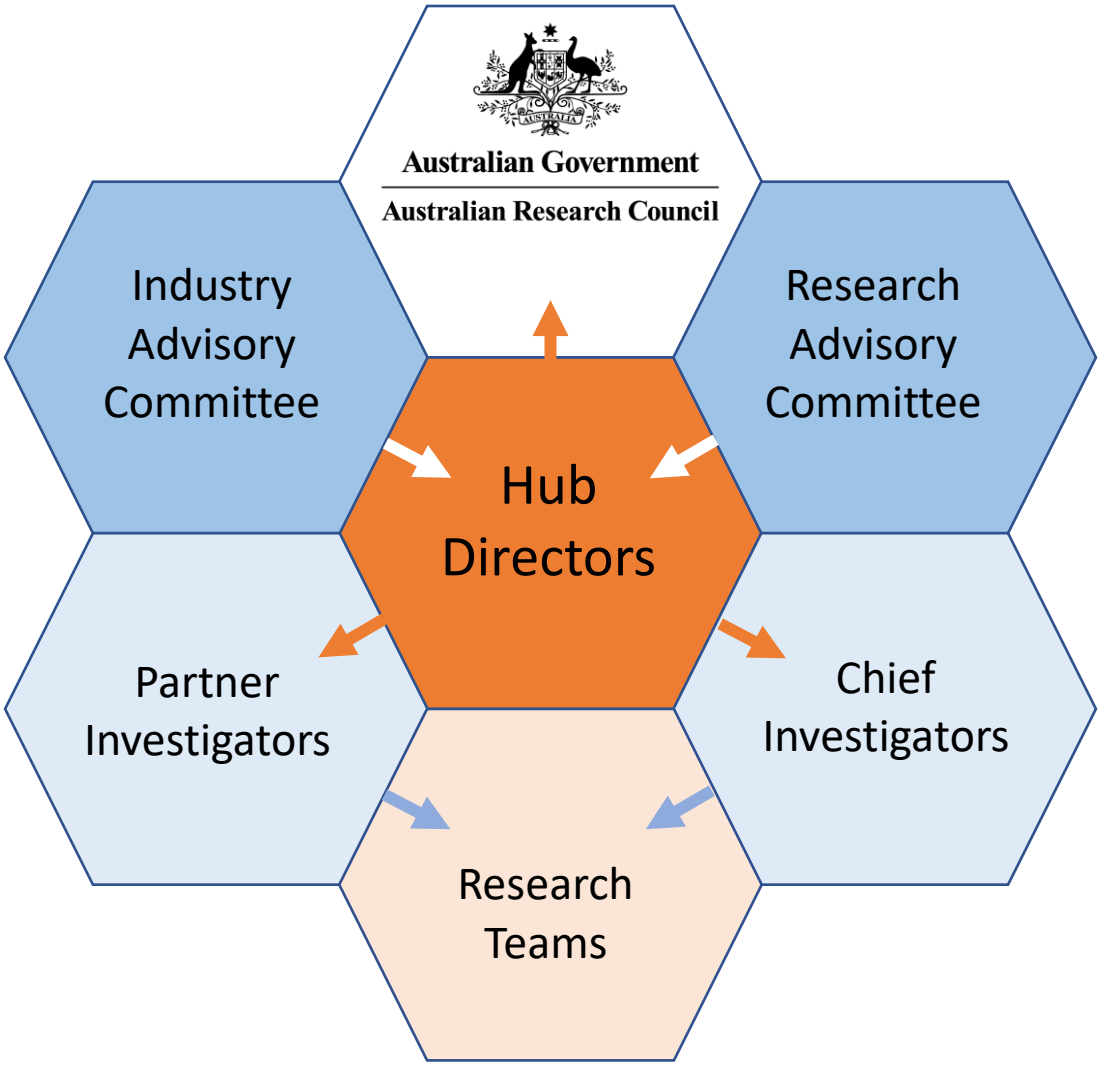
The Hub is governed by an executive team of Hub Directors with contributions from the advisory committees, Chief Investigators, Partner Investigators and research teams with support from the ARC.

Industry Advisory Committee

We would like to thank the contribution of the Industry Advisory Committee in assisting with optimising the Hub's research outputs and industry impact.

Committee members 2020:

- **Michael Haddy,** Director, Advanced Manufacturing Growth Centre
- **Stephen Hunt**, Chairman, Graphene Technology Solutions
- **Mohammad Choucair**, CEO, Archer Materials
- **Craig McGuckin**, Managing Director, First Graphene
- **Craig Nicol,** Managing Director, Graphene Manufacturing Australia
- **Dusan Losic**, Director, Graphene research Hub, University of Adelaide, Meeting Chair
- **Jacqui McRae**, Manager, Graphene Research Hub, University of Adelaide



3. INDUSTRY PARTNER SUCCESSES

first graphene
The world's leading graphene company

Quality graphene production – First Graphene manufactures tailored graphene

First Graphene (FGR) started the development of a graphene manufacturing process in collaboration with University of Adelaide which was scaled-up 2018 into an industrial plant with production capacity of 100 t/y. FGR is currently one of the world-leading producers of graphene with consistent and reliable high quality. This is a substantial breakthrough for the graphene industry and makes graphene more accessible for many commercial applications.

FGR have formed key collaborations across several industries to facilitate graphene-enhanced product development for broad applications such as:

- Composites
- Elastomers
- Fire Retardants
- Concrete
- Energy Storage
- Textiles

Their commercialization success story with many new products on the market includes: Face masks, safety boots, wear-liners for mining, composites for boats, additives for concrete, durable rubber floor mats and HDPE mesh for oyster farms. The FGR team now work with over 100 customers, delivering high quality graphene to Asia, Europe and the USA.

A collaboration with PlanarTECH enabled the rapid development and large-scale production of graphene-enhanced, reusable face masks early in the pandemic where FGR is now key graphene supplier.

Due to their exceptional growth and development, especially in the past year, FGR attracted the attention of WA premier, Mark Gowan, who visited the facilities in November.

FGR is Member of Graphene Engineering Innovation Center (GEIC) at Manchester University and became an Associate Member of the European Union Graphene Flagship. FGR, through its UK subsidiary, is the first Australian entity to be admitted to the EU consortium which is a significant success.

Advancing graphene technologies – Archer develops next steps for biosensor

Archer Materials have made substantial advances in their advanced materials research this year, including for their graphene biosensor research at Hub.

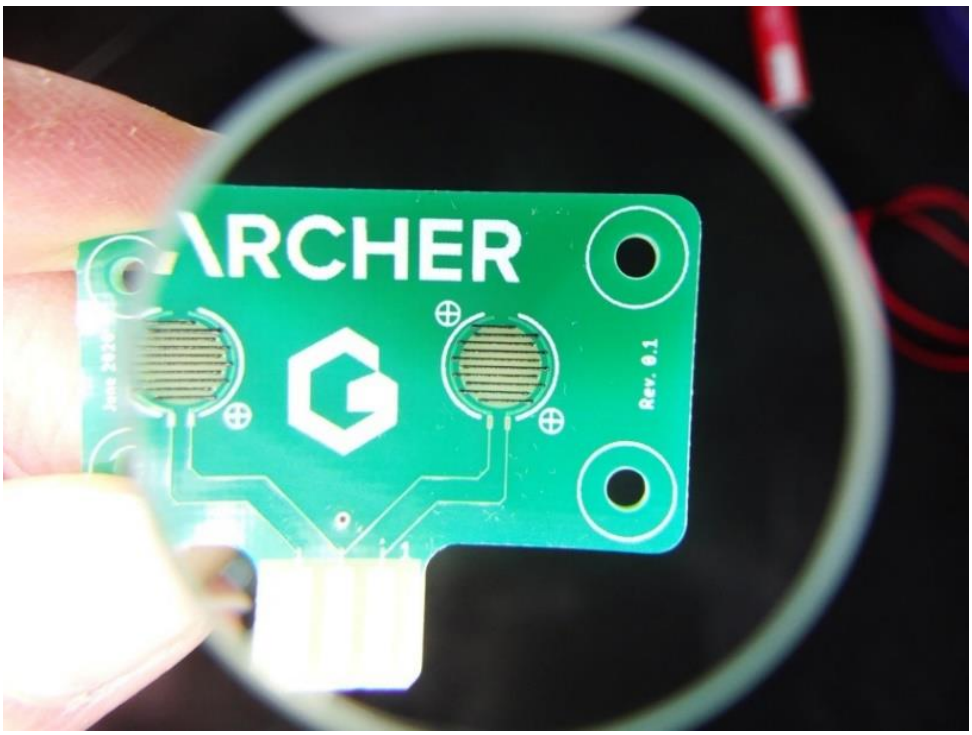
Archer successfully lodged a Patent Cooperation Treaty (“PCT”) for the graphene biosensor technology developed with the Hub Team.

The biosensors are produced by Hub-developed 2D printing technology using conductive graphene inks and have been shown to be effective in disease detection.

These biosensors have the potential to be rapidly scaled and deployed around the world for early, accurate detection and diagnosis of infectious diseases. This could assist in monitoring and controlling future pandemics.

A new 3D-printed cartridge has also been designed and fabricated to protect the biosensors and enable global distribution without damage.

The new cartridges enable the critical next step for large scale production, distribution and handling of the biosensors.



Growing the graphene industry – GTS launches on ASX as Sparc Technologies

Hub partner, Sparc Technologies has successfully listed on the Australian Stock Exchange (ASX) which now has a market capitalisation of over $20 million. This is a significant step for the company which has grown exponentially since joining the Hub in 2019.

Sparc aims to develop graphene-based technologies in three initial target markets:

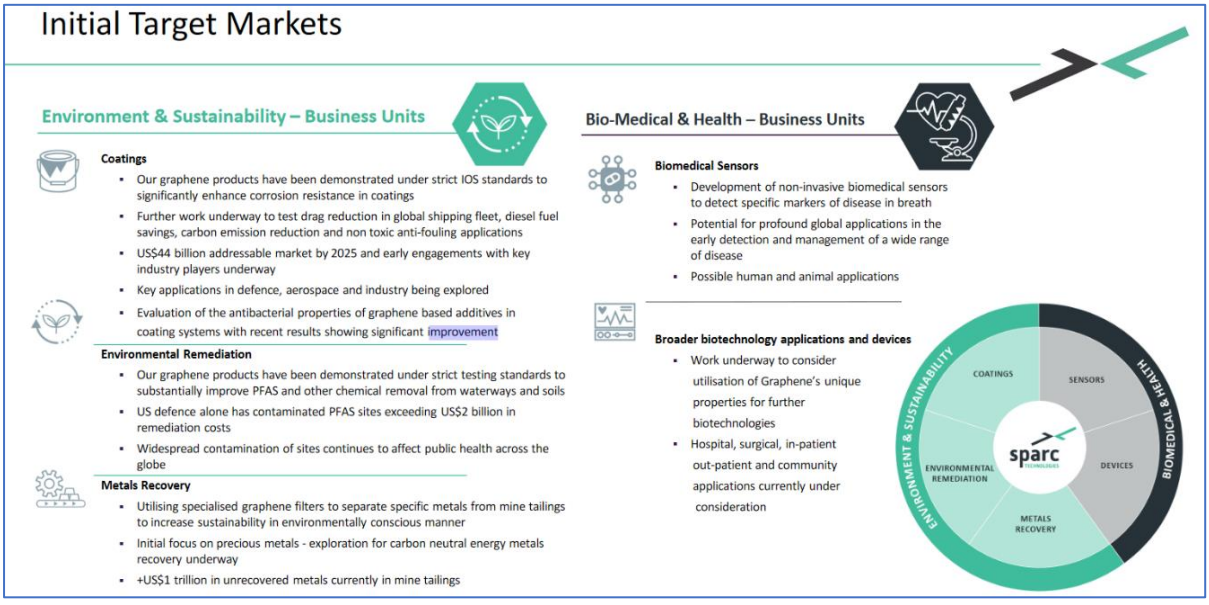
- Marine and protective coatings
- Environmental remediation
- Metals recovery from tailings

Sparc also formalised a long-term Strategic Partnership Agreement with the University of Adelaide. The $2M agreement will facilitate the development of graphene technologies in Australia and provide ongoing collaboration with University of Adelaide researchers beyond the lifetime of the Hub.

Sparc have licenced 3 Hub-developed technologies for potential commercial development and further contributing to a sustainable graphene industry in Australia:

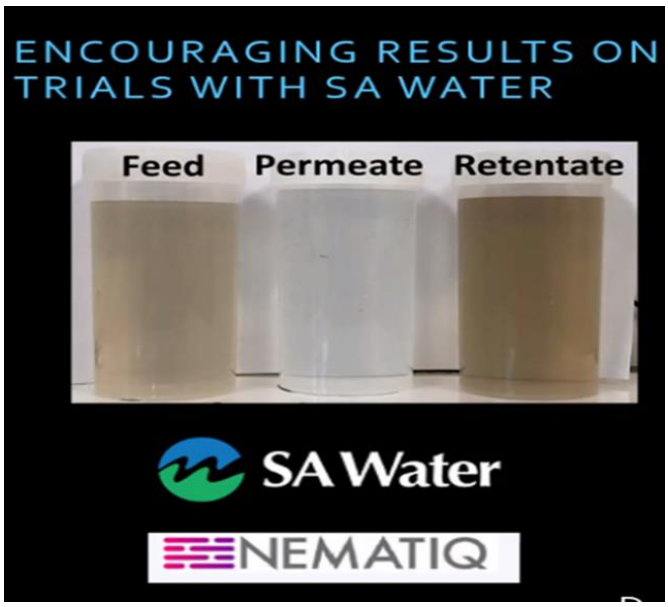
- Composite Graphene-Based Material for water and soil remediation and anti-corrosion
- Multipurpose Graphene-Based Composite for abrasion resistance
- Compositions/Materials for sound absorption

Sparc has also grown their operations with new premises secured in Adelaide. The centrally-located site will be used for large-scale testing and development of their graphene-enhanced technologies prior to commercialisation.



Graphene membranes for fresh water – NematiQ approaches commercial scale production

NemtiQ, the joint venture between Ionic Industries and Clean TeQ, continues to successfully scale up production of their Graphene-based water filtration membranes.

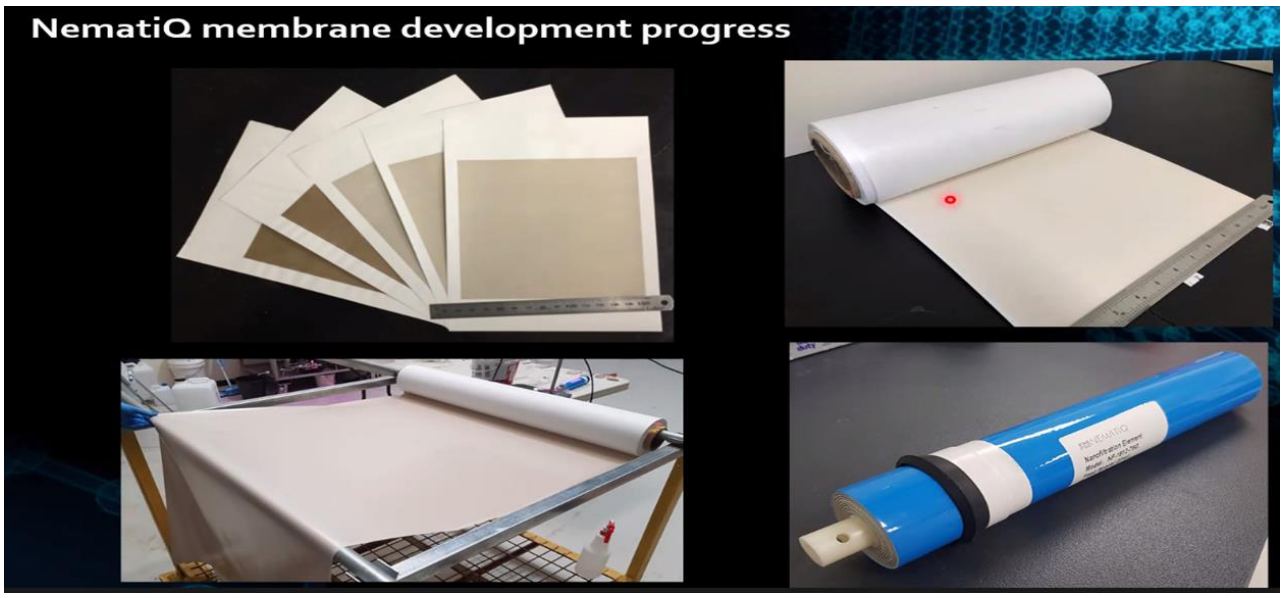


Collaborations with SA water has shown the efficacy of the membranes in eliminating contaminants and improving the quality of drinking water.

The membranes have demonstrated:

- High permeance
- High stability across pH
- MWCO approx. 1 kDa
- Ultra-low salt rejection

Research is also underway to assess the filtrations membranes for efficacy in PFAS removal from water.

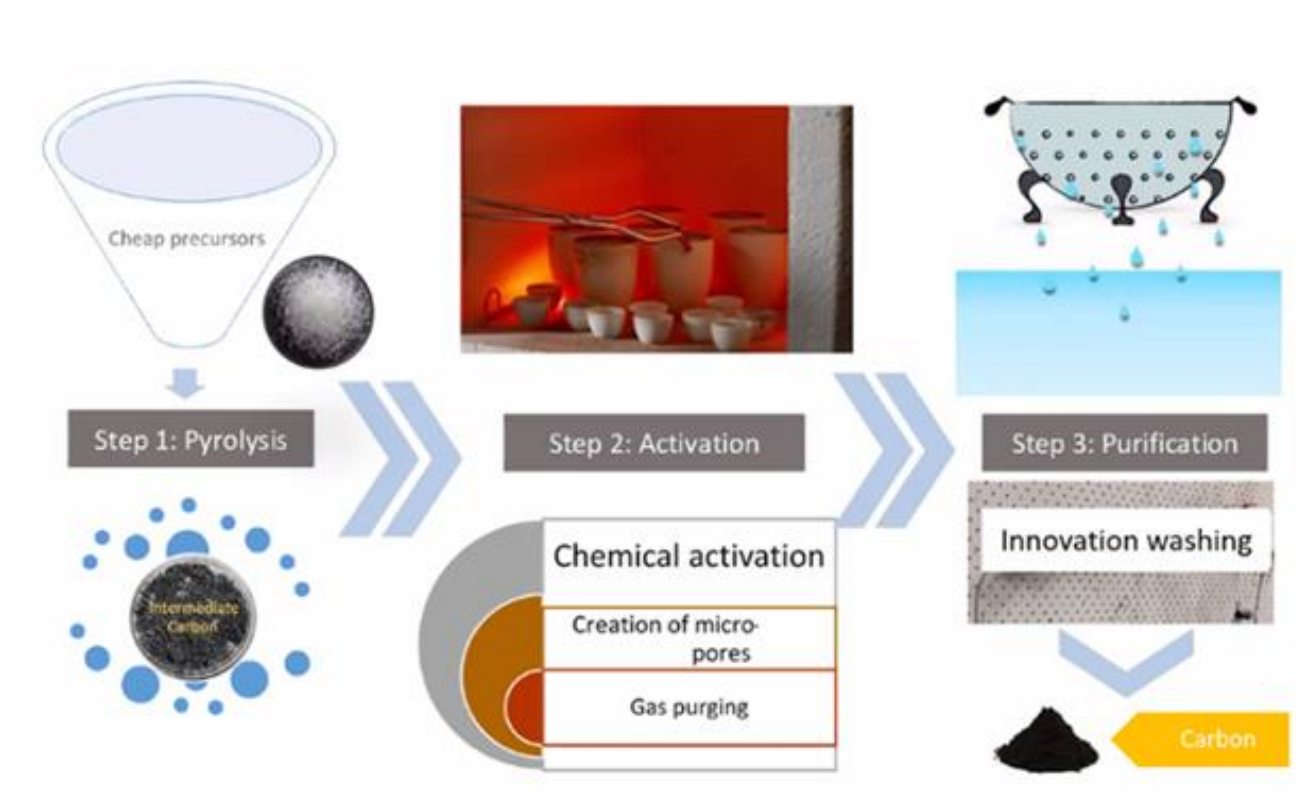


Powering the future with sugar cane – Cleanfuture Energy develop graphene batteries from a renewable resource

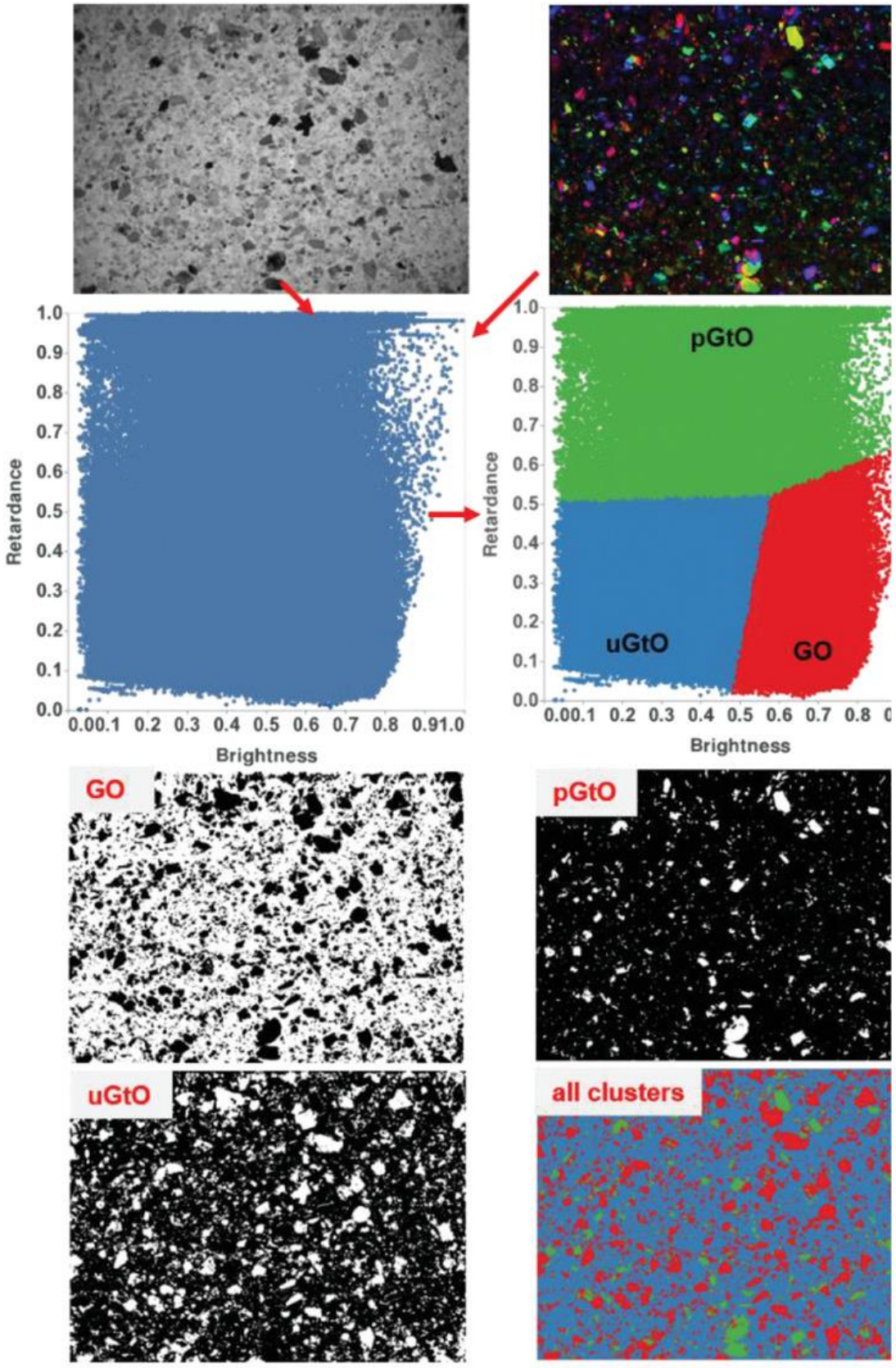
CFE has begun its scale up production for turning sugar cane into batteries. In collaboration with the Hub's Monash Team, CFE have developed a technique to transform waste sugar cane into carbon materials that can then be developed into highly efficient Li-S batteries.

The process has demonstrated the production of high purity carbon with tailor-made properties that can be readily scaled for mass production.

The company are on track to develop a large-scale production plant for sustainable energy production and storage.



4. RESEARCH HIGHLIGHTS



HUB RESEARCH PROGRAM OVERVIEW

Node 1: Fundamental challenges

- Graphene enabling research: production properties, processing, composites
- Graphene materials standardization and characterizations
- Environmental and health risks and impact of graphene materials and products

Node 2: Products development and translation

- GO membranes for water purification (NematiQ)
- Adsorbents for heavy metals (Sparc)
- Adsorbents for cleaning spilled oils (Sparc)
- Adsorbents for soil remediation (Sparc)
- Energy storage devices (CFE)
- Fire retardant paints (FGR)
- Polymer composite (FGR)
- Enhanced construction materials (FGR)
- Biosensors and medical devices (Archer)
- Graphene wearable antennas for high-volume applications
- Flexible electronics for biomedical application

Node 3: Translation and industry adoption

Research challenges in 2020

The COVID-19 pandemic of 2020 presented many challenges for researchers across the globe with lockdowns restricting lab access, delays on supplies and travels. However, from these challenges, the Hub team found new opportunities for success and innovation in many areas.

Record number of publications

With labs closed, researchers had time to focus on writing papers and catch up on publishing recent outcomes from the many Hub-related projects. The result was a record number of publications for the Hub in one year, reaching **over 60 peer-review journal articles**, double the expected number

This incredible result demonstrates the quality of research and the productivity of the team.

Workshops and skills development

Training the next generation of graphene researchers is a key aim for the Hub and lockdown presented an opportunity for teams to improve their skills outside the lab. Hub management organised several well-attended workshops for the team to learn and develop skills in presenting research to different audiences, writing and editing papers, and understanding IP and patents.

Digital presence

Travel restrictions limited opportunities for the Hub team to attend conferences and meetings, however digital opportunities bloomed.

The Hub team took advantage of the online platforms to attend more international conferences and showcase Hub research more broadly in webinars and virtual tours available to a global community.

Meetings also became digital as the Hub teams got together online for weekly catch-ups and check-ins to support each other in challenging times.

Innovation

Lab restrictions also led to research teams taking innovative measures to be more efficient and keep research tracking with close interaction with industry partners. Where occupational health and safety allowed, lab equipment such as 2D printers were set up in researchers' homes to maintain project momentum. This initiative enabled some projects to continue to gather data and results.

Opportunities were also explored for graphene to assist in the fight to beat the pandemic. First Graphene successfully partnered with PlanarTECH to develop and commercialise graphene-enhanced facemasks, now being produced in Thailand and distributed globally.

Sparc Technologies (formerly Graphene Technology Solutions) also applied for funding to use graphene-based sensing for the rapid non-invasive detection of Sars-cov-2 virus from breath samples.

International collaboration

We continued our workshop and collaborative links and with European Graphene Flagship remotely and strengthened our involvement in the ISO graphene standardization project and VAMAS interlaboratory evaluation program to develop new standards for graphene and promote rigorous quality control of graphene materials and related products.

Research challenges in 2020

Research highlight: Graphene composite production and dispersion

Graphene production in composites

CI Jun Ma and the University of South Australia Hub team developed a revolutionary new concept for in-situ graphene preparation and efficient mixing with polymer matrix.

This method significantly advances the mechanical and electrical properties of graphene-polymer composites that has not been achievable using conventional methods.

The results, published in the journal, Composite B, were produced from an international collaboration involving 5 Universities in several countries including from Australia, China and Taiwan.

This new method enables a more stream-lined approach to the production of graphene-polymer composites, that could change the conventional way of making graphene polymer composites and make a significant impact in this field across many applications.

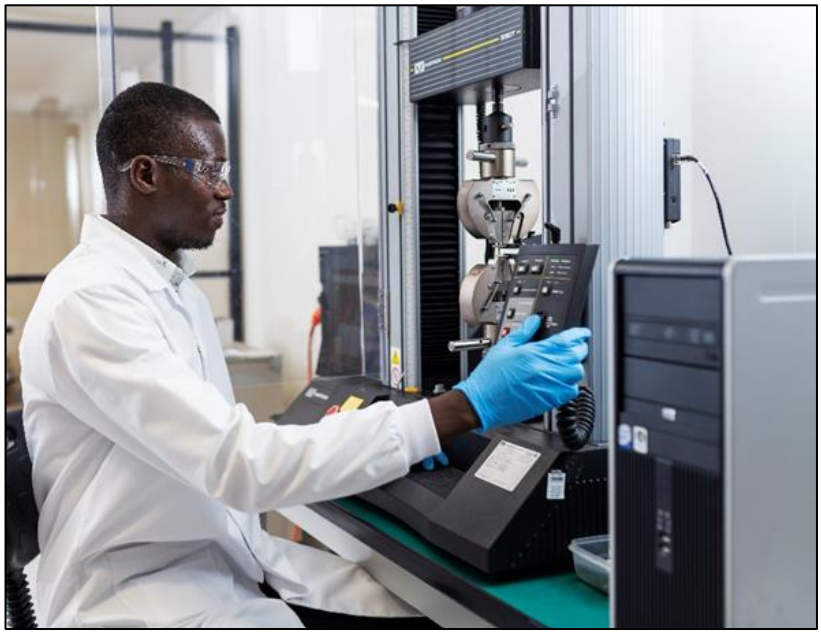
A patent application has been submitted for this new process.

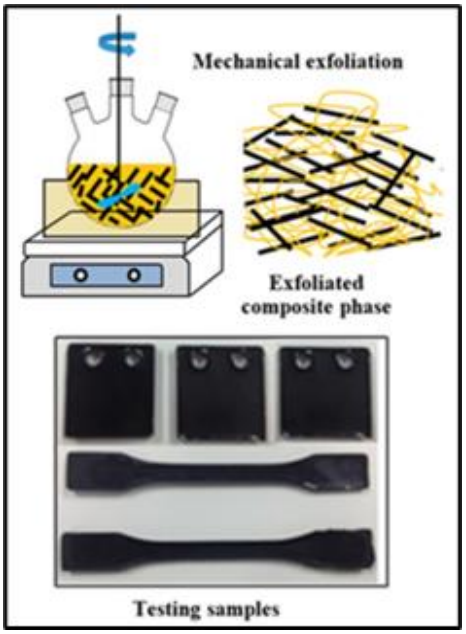
Graphene-MOF composite for hybrid supercapacitors

CI Deepak Dubal and his team at QUT have developed a new hybrid supercapacitor device by combining a battery-type positive electrode made from Graphene-Metal Organic Framework (Graphene/MOF) hybrid material and a capacitor-type negative electrode made from titanium carbide.

To produce the device, they combined chemically-modified graphene with a nano-structured metal organic framework (MOF). This unique structure meant the resulting supercapacitor has properties that could make it suitable for use in energy storage, solar cells, and biology applications.

This unique hybrid structure allows the device to reach an energy density close to rechargeable nickel metal hydride batteries while offering power 10 times greater than that of lithium batteries. The device has the potential to make a substantial impact in the fast-developing field of novel energy storage devices.



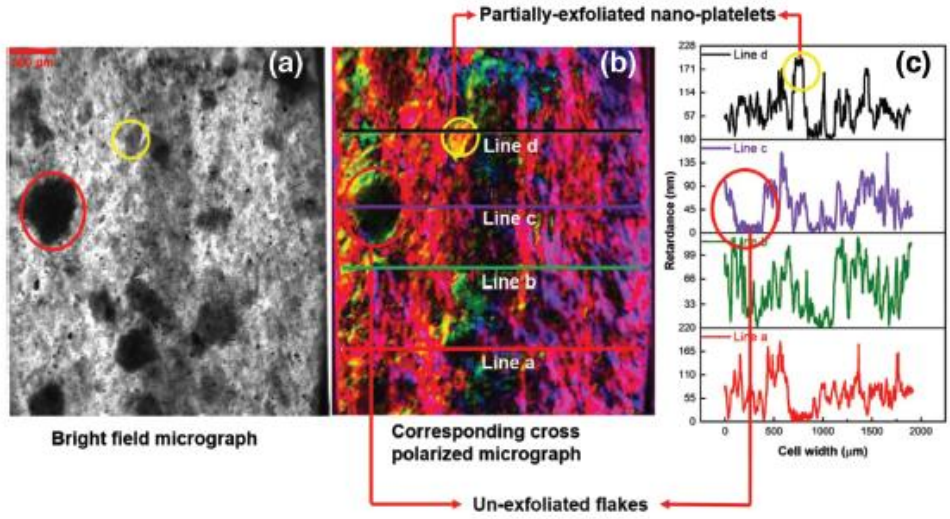


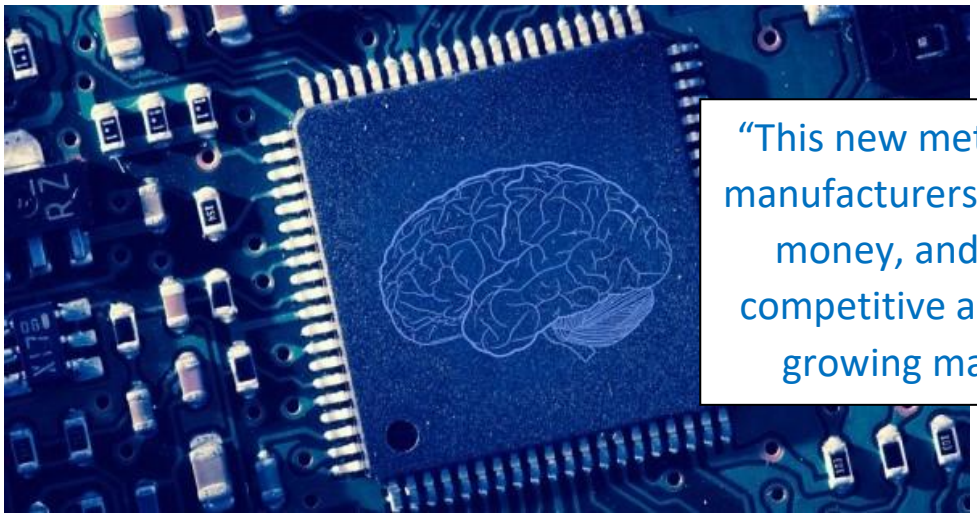
Research highlight: Machine learning method for rapid graphene characterisation

Deputy Director, CI Mainak Majumder, and his Monash University team have developed a machine learning method that could reduce the time for characterising graphene to under 14 minutes. Characterising the structural properties of graphene such as the number of layers and purity is essential for production monitoring and to accurately assess potential applications.

This is one of most critical problems in growing graphene industry because the process normally involves the use of very expensive and time-intensive techniques such as TEM, Raman and AFM. The developed algorithm can rapidly detect, classify and quantify exfoliated graphene in a dispersion using data from a quantitative polarized optical microscope. Monash team is considering commercialization of this new exciting quality control technology.

“This will save manufacturers vital time and money, and establish a competitive advantage in a growing marketplace,” said Prof Majumder.





“This new method will save manufacturers vital time and money, and establish a competitive advantage in a growing marketplace”

Research highlight: Graphene characterisation and standardisation

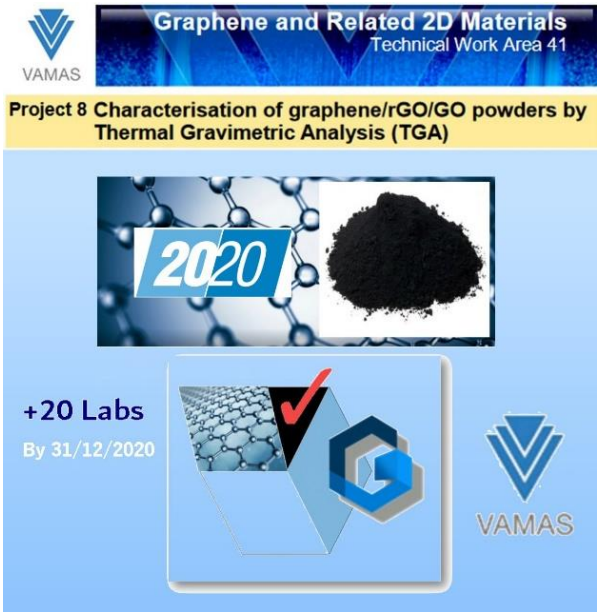
Director, CI Dusan Losic, and the University of Adelaide team established a library of graphene materials and graphene characterization methods and also developed several new methods for effective quality control of graphene materials and products.

This is one of largest challenges of growing graphene industry with many “fake” graphene materials being marketed and a lack of robust methods for their characterization. This capability developed in the Hub is now available to Industry partners and international graphene industry.

The Hub team was also invited to participate ISO standardization committee on graphene and working groups for the development of new ISO standards for chemical characterization of graphene materials.

CI Losic, was invited to lead the Versailles Project on Advanced Materials and Standards (VAMAS) international project to improve graphene standardisation and enable consistent characterisation. This project involves +20 international labs and experts across 5 continents. Participants so far include labs in Brazil, Mexico, USA, UK, EU, China, Japan, South Korea and Australia.

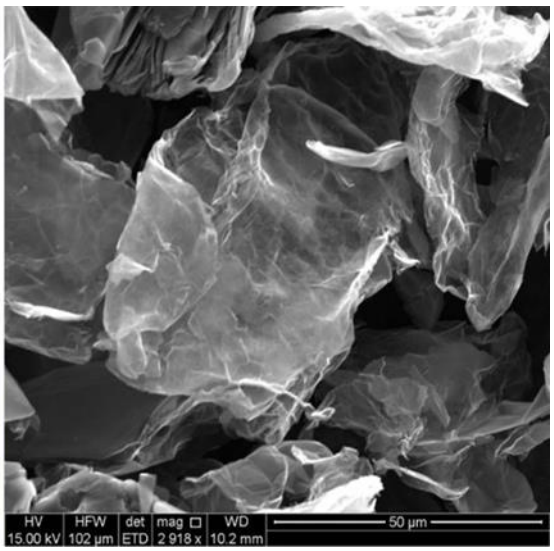
The aim of the project was to coordinate a standardised method for thermogravimetric



analysis (TGA) of graphene and related materials. TGA is used as a key measure for characterising graphene and developing a standard TGA method is vital to growing a sustainable graphene industry world-wide.

Results will assist in developing a new ISO standard: ISO/PWI 23359 ‘Chemical Characterisation of graphene and graphene oxide in powders and suspensions’.

“This work is critical to give researchers, industry and consumers confidence as they develop, manufacture and use these materials,” said Dr Jan Herrmann, National Measurement Institute



Research highlight: Graphene-enhanced materials

Thermoplastic polymers

First Graphene has demonstrated improvements in the performance of High-Density Polyethylene (HDPE) materials. The addition of First Graphene's products improved the strength, wear resistance and longevity of HDPE products. These initial results confirm the potential of graphene as a high performing additive for the global HDPE industry.

HDPE is a thermoplastic polymer widely used in packaging material for cosmetics, food and beverages as well as for corrosion-resistant piping, geomembranes and plastic timbers. The global market for HDPE was estimated at USD 59 Billion in 2015

Low CO_2 construction materials

First Graphene (FGR) and the UoA team have shown that adding pristine graphene to cement mortars can improve the compressive strength and reduce the CO_2 emissions of concrete productions.

Compression strength was substantially improved by over 30% when graphene was added to concrete at only 0.1%w/w.

The large flakes of FGR's pristine graphene industrially produced from Sri Lankan vein graphite also reduced the water permeability of the concrete and potential for re-bar corrosion.

first graphene
The world's leading graphene company

Research highlight: Graphene-enabled environmental solutions

Mine tailings recovery

Waste produced from the mining industry contains residual precious and toxic metals that are a potential resource.

Hub-developed graphene functionalized adsorbents have been assessed for the selective and efficient removal of specific metal ions.

The developed technology is more effective than existing commercial adsorbents. Work is now underway to increase the scale of the technology with a view to commercial application.

The research outcomes have already produced one provisional patent and extensive know-how.

Soil remediation

PFAS (Poly- and perfluoroalkyl substances) PFAS contamination of soils is emerging as a major ongoing Australian public health issue. PFAS include >500 long-lasting synthetic chemicals found in firefighting foam, landfill and wastewater treatment.

Graphene-based technologies have been developed that are more effective than activated carbon in binding toxic PFAS molecules and preventing their uptake and bioaccumulation in the food-chain.

Further development of this technology will potentially enable commercial-scale remediation of PFAS-contaminated soil.

LICENCING, TRANSLATION, COMMERCIALISATION

Fire protective coatings

First Graphene (FGR) have taken the next step to commercialising Hub-developed fire-retardant coatings, branded as FireStop™, by entering into a non-disclosure agreement with international company, USA based supplier of fire and thermal protection products trading in Australia as ExFire.

The UoA team have continued work on final testing of FireStop™ using FGR's graphene for various applications that will be defined by the new partner. This is exciting progress that will enable effective distribution and application of this outstanding product.

Graphene composites

FGR have formed collaborations with several industry partners to develop and commercialise products containing their graphene-enhanced composites produced in collaboration with the Hub.

These superior products are more durable and long lasting than existing products and can improve the performance and quality of recycled materials. Products include wear liners for mining equipment, safety boots, mats made from recycled material, oyster baskets used in aquaculture.

Graphene dispersion in water

CI Namita Choudhury and the RMIT Hub team developed a liquid exfoliation process for efficient for mass production of high-quality graphene dispersions in water.

Currently, the market is dominated by graphene oxide derivatives that are low quality and involve harsh chemical oxidation/reduction processes. Graphene exfoliated in liquids have higher quality, but they rely on toxic solvents and excessive additives to be stable in the dispersions, making them unusable in most practical applications.

The new method induces amphiphilic molecules to be strongly adsorbed onto the surface of graphene, promoting exfoliation and stabilizing the exfoliated graphene sheets in water. This breakthrough could allow for graphene produced by Hub technology to replace graphene oxide in the global market.

A patent application has been submitted for this new invention and Sparc Technologies have been engaged as the commercialisation partner to bring the new technology into large-scale manufacturing processes.

5. COMMUNICATIONS AND OUTREACH

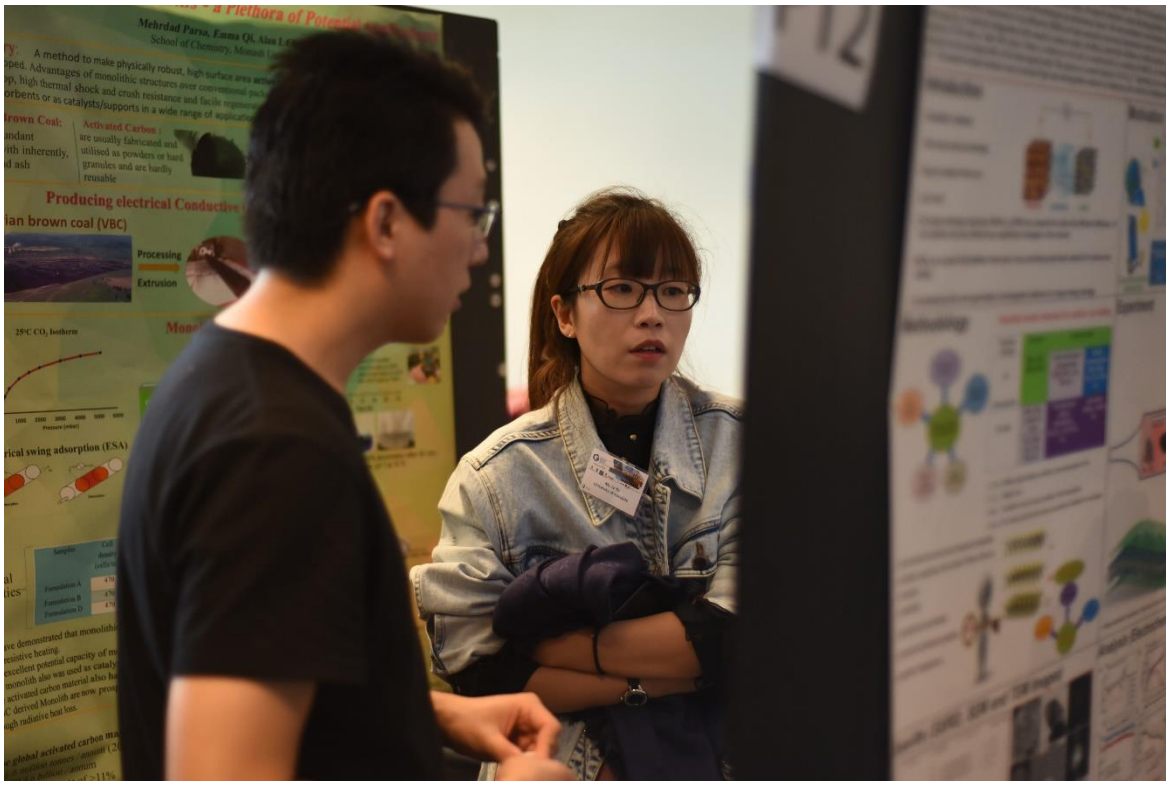


Photo credit: Sky Li, University of Melbourne

ARC Graphene Hub Workshop 2020 highlights

Graphene experts from across Australia came together for the ARC Graphene Hub's 2nd Annual Workshop at Monash University this year. The Workshop attracted over 50 Hub members, industry partners and guests from related research groups.

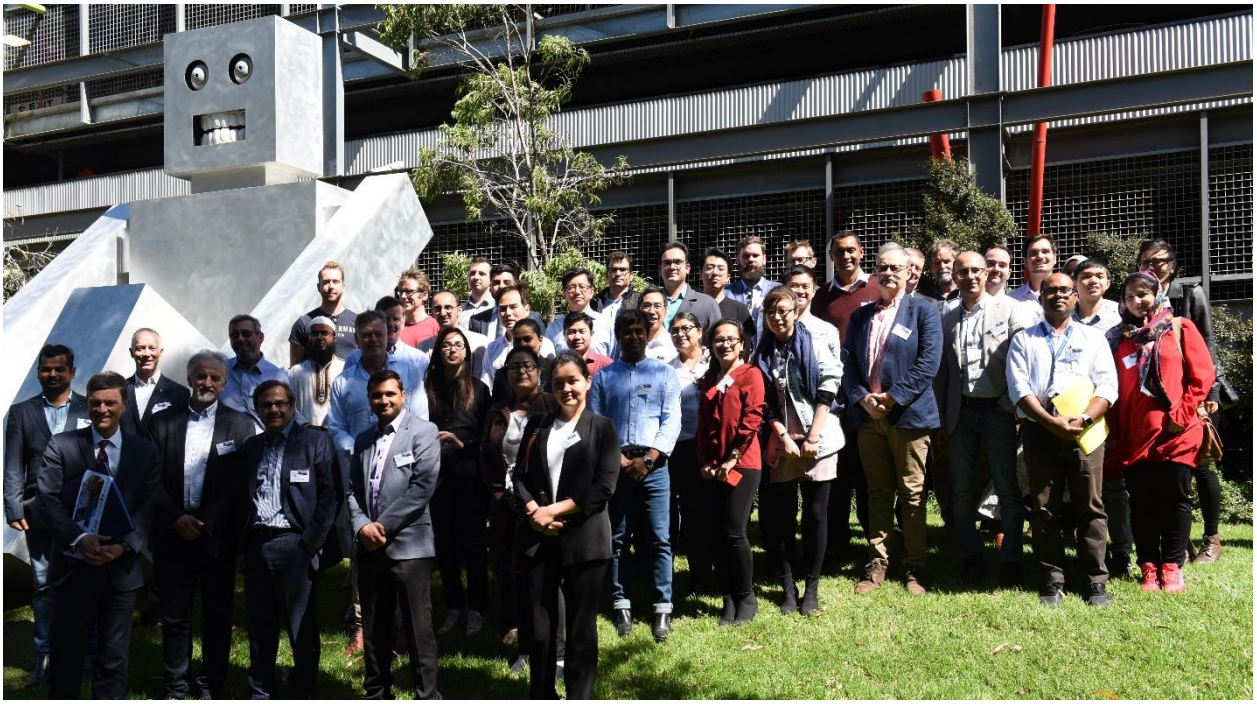
Graphene production, membranes, composites, batteries and sensors enabled by graphene and 2D materials featured in the workshop.

The program included keynote presentations from the Hub Chief Investigators as well as 11 oral and 18 poster presentations from the Hub research team.

Workshop Best Presentation award winners included:

- Tuan Sang Tran, PhD (RMIT): Best Oral Presentation - Multi-functional graphene dispersions
- Gargi Mukhopadhyay, PhD (Monash University): Best Poster - Electrodes for biosensing applications

The Workshop was supported by GTS and Ezzi Vision and organised by Tanesh Gamot, Sky Li, Kamrul Hassan, Pei Lay Yap and Jacqui McRae.



ARC Graphene Hub Workshop 2020 highlights

Key in-person conferences and workshops

ICONN 2020

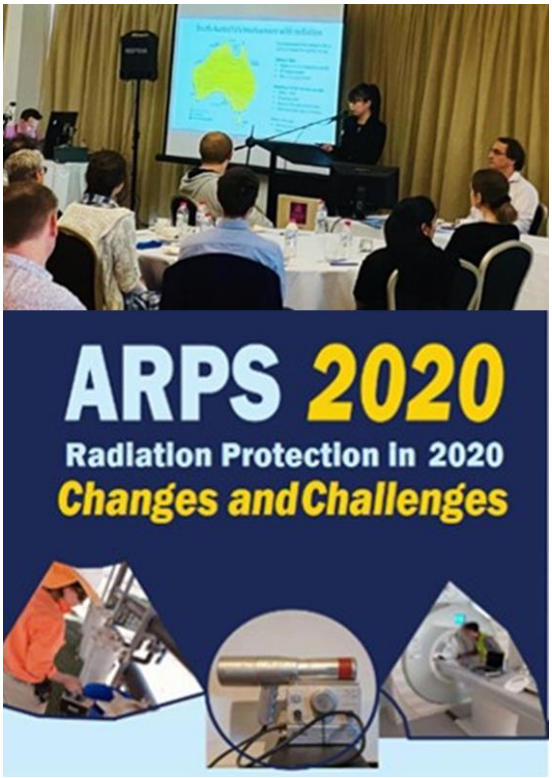
Hub research was showcased at this year's International Conference on Nanoscience and Nanotechnology held in Brisbane in February. The conference attracted around 700 attendees from over 20 countries. Many Hub members presented their work including:

- CI Mainak Majumder (Monash): Translating novel battery and supercapacitor technologies through industry partnerships
- CI Jun Ma (UniSA): Solvent-free synthesis of epoxy/graphene nanocomposites
- CI Namita Choudhury (RMIT): Advanced self-assembled biomimetic protein platform
- Dr Tung Tran (Uni Adelaide): Quantum resistive sensors made of graphene and metal organic frameworks for VOC biomarkers analysis
- Mr Kamrul Hassan (Uni Adelaide): Extrusion micro-printing of conductive graphene inks for wearable electronics and sensing applications
- Ms Pei Lay Yap (Uni Adelaide): Polyamine Functionalised composites for effective water remediation (poster award)

The suite of projects presented by Hub researchers is an excellent demonstration of the breadth of research conducted by the Hub and the broad interest of these techniques and materials.

ARPS 2020 Radiation Protection

PhD Student, Le Yu (Uni Adelaide) presented her work at The Australasian Radiation Protection Society (ARPS) 2020 ARPS conference, Adelaide, on developing a new generation of materials for radiation shielding. Her presentation raised great interests from Australian radiation protection community on research from the Hub team.



Key international conferences and workshops

EU Graphene Flagship

Hub research outcomes and collaborations were highlighted in the EU Graphene Flagship's digital event: Graphene for Research Innovation and Collaboration, held September 22-24. This event replaced the annual Graphene Week conference and EU-Australia Graphene Workshop.

CI Dusan Losic led "Session 2: Around the World with Graphene" with a presentation showcasing the emerging technology from the Hub and around Australia.

The session highlighted the importance of collaborations across industry, research groups and continents to improve graphene production, standardisation and product development.

The presentation included an invitation to the next EU-Australia Graphene Workshop co-hosted by Dr Ken Teo of Aixtron and CI Losic to be held in 2021.

Industry presentations – Australian Graphene Industry Association

Deputy Director, CI Mainak Majumder, presented the Monash Hub team's energy storage research at the Australian Graphene Industry Association webinar "Energy Storage + Graphene".

CI Majumder's presentation, entitled "Iodinated-graphene oxide as a manufacturable platform for safe and sustainable energy storage solutions" showcased the ultra-thin pouch supercapacitors developed by Dr Meysam Mirshekario.

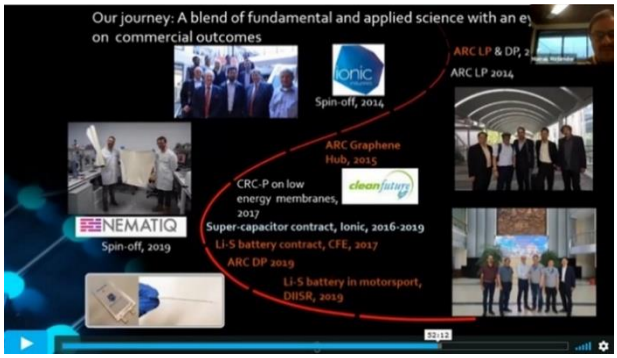
These supercapacitors were benchmarked against a similar commercial product, demonstrating the efficacy of the graphene component.

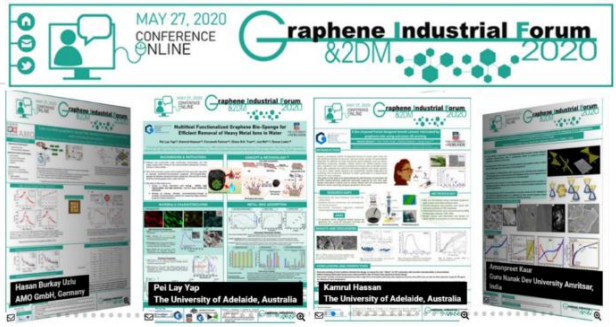
Graphene and 2D Materials International Industry Forum

PhD students, Kamrul Hassan and Pei Lay Yap, presented their research as Flash Posters at the first online forum on May 27th Organized by European Graphene Flagship.

The innovative new format was developed in response to the cancellation of most major scientific and technological conferences and successfully provided an opportunity to present the latest research from the sector.

The novel approach combined oral presentations and flash posters to highlight research outcomes to a broad international audience of researchers and industry representatives.





Outreach and community engagement

3 Minute Thesis success

The challenge of describing a PhD worth of research in just 3 minutes was accomplished by PhD student, Pei Lay Yap (Uni Adelaide) who successfully made it to the School finals this year's 3 Minute Thesis (3MT) competition. The nationwide competition is designed to help PhD students hone their communication skills by presenting complex scientific ideas and research outcomes within a few minutes.

Pei's Hub research into graphene-enhanced water purification technology is captured by her story on "Magic bio-carpet for clean water".

ARC Graphene Hub on social media

Research outcomes from the Hub are being broadcast across social media as well as standard media channels to great success.

The Hub's Twitter following has tripled over the past year with regular tweets about journal publications, conferences, workshops, industry partner success stories and team social activities.

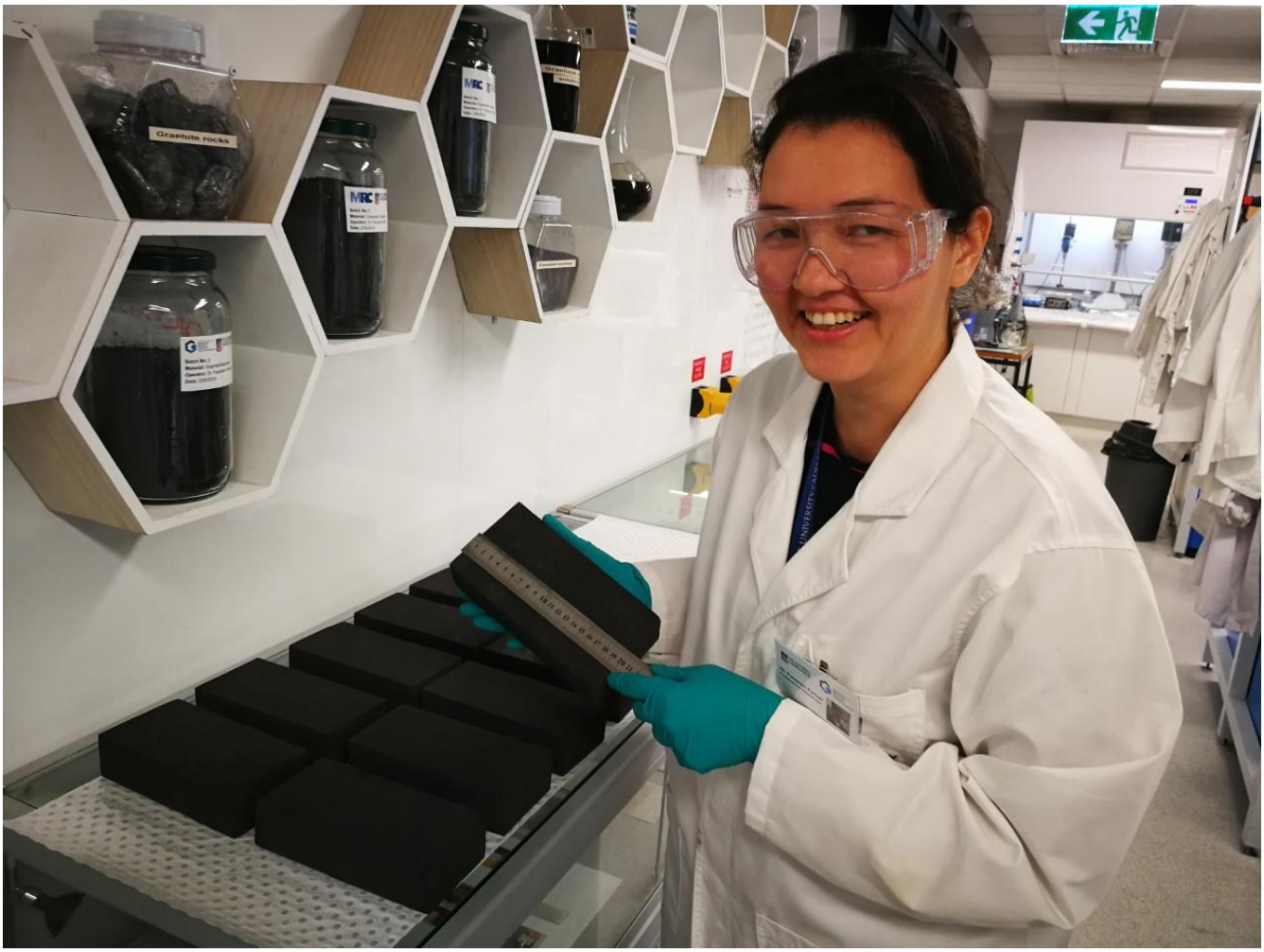
Novel techniques featured on YouTube

PhD student, Arash Mazinani (Uni Adelaide), developed a unique surface modification technique called plasma electrolytic oxidation (PEO) to improve properties of titanium surgical implants. This technique, combined with graphene, generates an antimicrobial surface on the implant, minimising surface contamination and the likelihood of infections after surgery.

Surface engineering with PEO can also be applied to other biomedical applications and has potential to be used in space and defence applications.

The many applications and the novelty of the technique prompted Arash to produce a demonstration video, now available on the Hub's YouTube Channel.

6. TEAM ACHIEVEMENTS



TRAINING FUTURE LEADERS

PhD Success: Dr Pei Lay Yap

Dr Yap, supervised by Prof Losic and Dr Diana Tran, was the 11th successful Hub PhD completion.

Her thesis, entitled "Development of Advanced Graphene-based Composites for Water Purification" received outstanding reports from world leading graphene experts as PhD thesis Examiners.

During her PhD, Dr Yap generated 12 journal papers - 6 as the first author, 10 conference presentations, and made a significant contribution to the Hub research in the field of application of graphene for water purification.

Dr Yap also received multiple awards for research and presentation excellence:

- Poster award – ICONN 2020
- Presentation award – American Chemical Society 2020
- 3 Minute Thesis Finalist – University of Adelaide Faculty of Engineering, Maths and Computer Sciences

PhD success: Dr Van Dac Ho

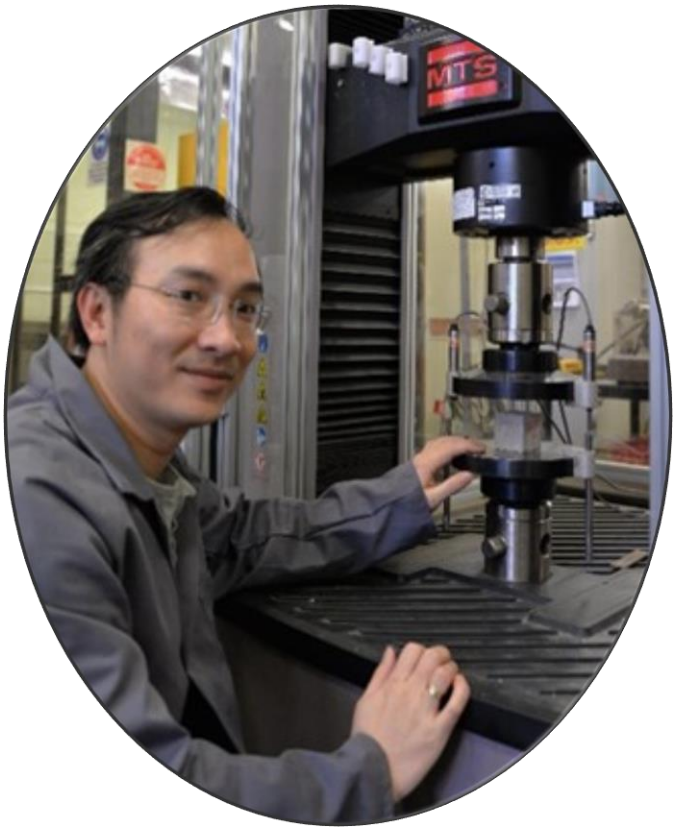
Dr Ho was supervised by CI Losic and A/Prof Alex Ng and his project “Development of Next-Generation Construction Materials with Graphene Additives” was sponsored by Industry partner, First Graphene.

Results from the project, published in 4 journal papers, show how graphene addition can improve many properties of concrete materials, opening exciting opportunities for the expansion of graphene use in construction industry.

Industry partner, First Graphene, has celebrated Dr Ho’s research outcomes with media releases, blogs and ASX reports highlighting the efficacy of graphene-enhanced concrete structures. These research outcomes will have substantial long-term benefit for the building and construction industry.

Dr Ho’s research uncovered many benefits to incorporating graphene into concrete including:

- Stronger yet lighter concrete structures
- Potential improved longevity of concrete structures
- Reduction in the carbon footprint caused by cement-based products
- Results from his work will be translated into practical use of graphene additives in cement and construction industry.

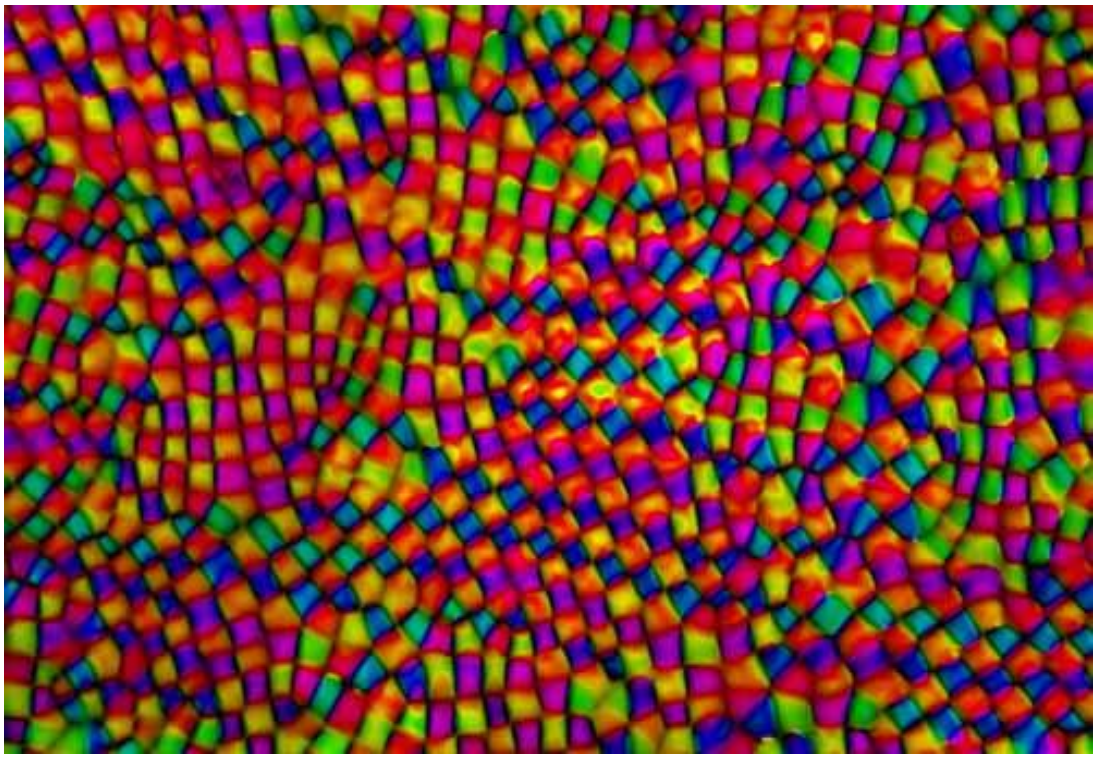


PhD success: Dr Joynul Abedin

Dr Joynul Abedin completed his PhD with CI Mainak Majumber, Monash University. His project was entitled: “Structure–Processing–Property Relationships in Graphene Oxide Materials” and led to publications in esteemed journals such as ACS Nano.

In particular, his work on the classification of graphene dispersions using machine learning approach led to a publication in Advanced Science. This high-throughput method enables the quantitative assessment of graphene/graphene oxide dispersions within half an hour, a substantial reduction in time from the traditional labour-intensive approach.

Dr Abedin presented at many conferences including the EU Flagship’s 2019 Graphene Week conference in Helsinki. He also received the first prize for his artistic Nano-Image at the Monash Micro Imaging Competition. The image, named “The Sea of Parabola” (below), shows a parabolic focal conic pattern of cholesteric liquid crystal phase formed by Cellulose nanorods.



Training, mentoring and skills development

Honours students showcased at Ingenuity

The Hub team have trained +50 Master, Honours and Summer students in 3.5 years.

This year, Honours students presented their graphene-focused research projects at Ingenuity, an annual event for researchers and industry hosted by the Faculty of Engineering, Computer and Mathematical Sciences, UoA.

Hub projects also gained top honours with work by T. Quach, T. Nguyen and T.T.A. Tran, being awarded the Best Overall Chemical Engineering and Advanced Materials Projects award.

The team's research focused on developing functionalized graphene composites for environmental applications including removing oil from water.

Mentor program

This year the Hub introduced a formal Mentor Program to introduce the Hub's early- and mid-career researchers to academic and industry leaders. The support from mentors enables the mentees to further their networks and better define career objectives.

We are very grateful for the support provided by our mentors in the 2020 program, including:

- Prof Tara Pukala, University of Adelaide
- Prof Justin Chalker, Flinders University
- Dr Anthony Brewer, WearOptimo

The success of the program and positive responses from the mentees have prompted a continuation of the program in 2021.

Professional skills development

Lab closures provided opportunities for further professional development of Hub researchers. Online workshops were organised and well-attended that allowed teams across different universities to improve their skills.

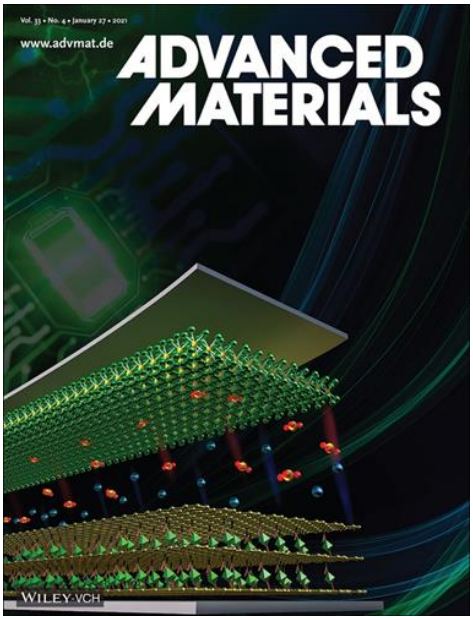
Workshops included several writing and editing courses to improve the efficacy of writing peer-reviewed publications and conveying results and research significance.

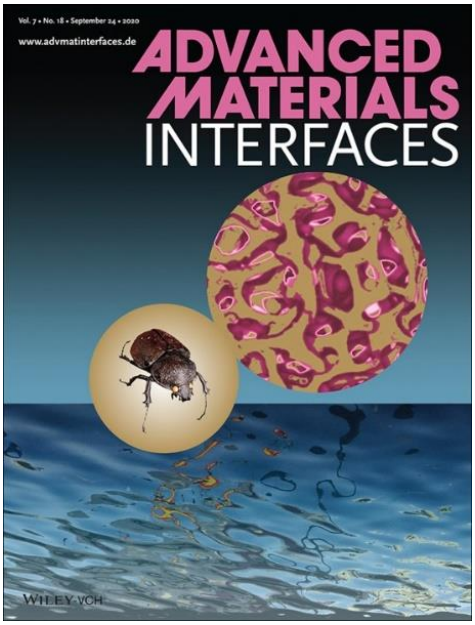
Presentation workshops also enabled teams to build their skills in effective and persuasive academic presentations and communicating to the broader community.

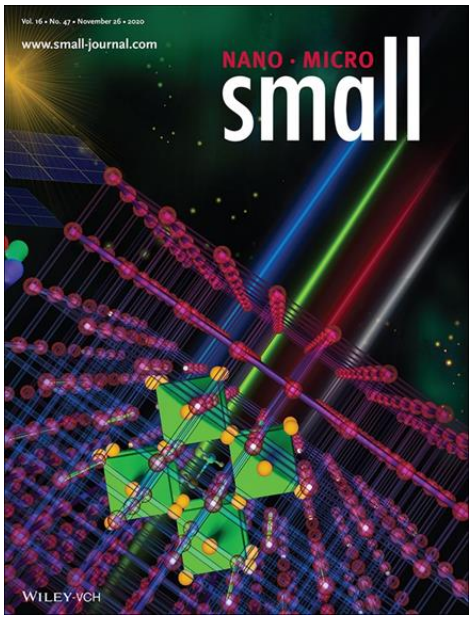
HUB TEAM BUIDING, SOCIAL LIFE AND EVENTS

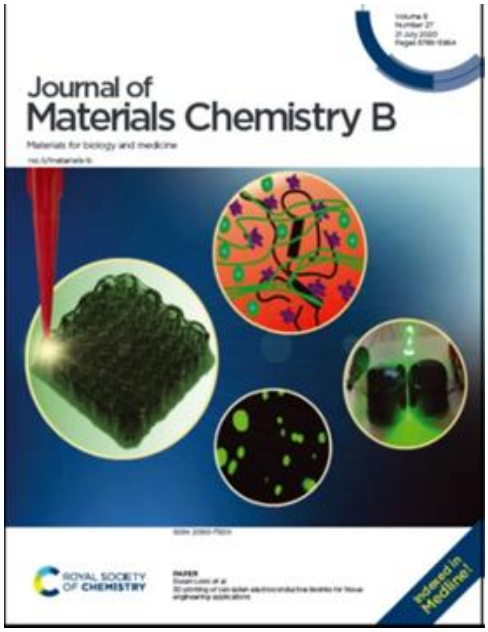
Hub teams were very active outside University to keep with many celebrations, social and team building events after COVID-19 lockdowns to keep the high spirit and enthusiasm of the teams.

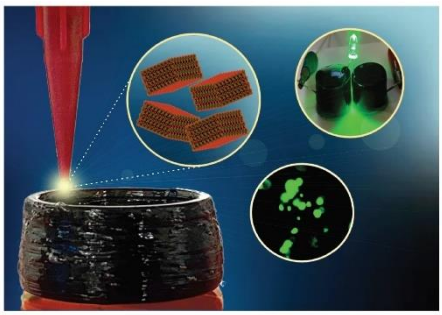
7. RESEARCH OUTPUTS 2020







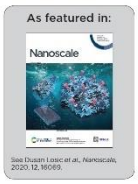




Showcasing research from Prof. Dusan Losic's group at the School of Chemical Engineering and Advanced Materials, The University of Adelaide, Adelaide, Australia.

3D bioprinting of cell-laden electroconductive MXene nanocomposite bioinks.

A new electroconductive cell-laden bioink composed of Ti_3C_2 MXene nanosheets dispersed homogeneously within Hyaluronic acid/Alginate (HA/Alg) hydrogel has been introduced that displayed excellent rheological properties, allowing the fabrication of multilayered 3D structures with high resolution and shape retention. The introduction of Ti_3C_2 MXene nanosheets within the HA/Alg hydrogel endows the electrical conductivity to the ink, addressing the poor electrical conductivity of current bioinks that mismatch with physico-chemical properties of tissue.



The Hub research outputs generated from 2020 include over 65 published/accepted journal papers, 11 conference abstracts and presentations, and 2 patents

Patents

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Conference abstracts and presentations

1. Pei Lay Yap, Kamrul Hassan, Farzaneh Farivar, Diana N.H. Tran, and Dusan Losic, Multi-thiol Functionalized Graphene Bio-sponge for efficient Removal of heavy metals, Graphene Industrial Forum 2020, May 27 2020, EU Graphene flagship online conference.
2. Kamrul Hassan, T.T. Tung, Nathan Stanley, D. Losic, A bio-inspired fractal designed breath sensors fabricated by graphene inks using extrusion 3D printing, Graphene Industrial Forum 2020, May 27, EU Graphene Flagship online conference.
3. Yap, P. L.; Tung, T. T.; Kabiri, S.; Matulick, N.; Tran, D. N. H.; Losic, D., Low cost Polyamine Modified Graphene Composites for Effective Mercury Remediation in waters, American Chemical Society 259th ACS National Meeting

Philadelphia, PA March 22-26, 2020 (Online conference) ENVR 770 p 286.

4. T.S. Tran, Engineering of graphene dispersions into three-dimensional macrostructures. Keynote, ICNASA 2020, Swinburne University of Technology, 31 Jan - 3 Feb 2020.
5. T.S Tran, Interfacial Engineering, Exfoliation and Functionalization of Multi-functional Graphene Dispersions. Second Annual ARC Graphene Hub Workshop, Monash University, 12-13 March 2020 (Best Presentation Award).
6. Kamrul Hassan, T. Tung, Nathan Stanley, D. Losic, Extrusion micro-printing of conductive graphene inks for wearable electronics and sensing applications, ICONN 2020 – International Conference on Nanoscience and Nanotechnology, 9-13 Feb 2020, Brisbane.
7. Pei L. Yap, Tran Tung, S. Kabiri, D.N.H. Tran, D. Losic, Polyamine-Functionalized Graphene Composites for Effective Water Remediation, ICONN 2020, 9-13 Feb 2020, Brisbane.
8. Jun Ma et al Solvent-free synthesis of epoxy/graphene nanocomposites, ICONN 2020, 9-13 Feb 2020, Brisbane ICONN 2020, 9-13 Feb 2020, Brisbane.
9. M. Majumder et al, Translating novel battery and supercapacitor technologies through industry partnerships, ICONN 2020, 9-13 Feb 2020, Brisbane.
10. Namita R. Choudhury, Advanced self-assembled biomimetic protein platform, ICONN 2020, 9-13 Feb 2020, Brisbane.
11. Tung Tran, Quantum resistive sensors made of graphene and metalorganic frameworks for VOC biomarkers analysis, ICONN 2020, 9-13 Feb 2020, Brisbane.