



The ARC Research Hub for
**GRAPHENE
ENABLED
INDUSTRY
TRANSFORMATION**

ARC GRAPHENE RESEARCH HUB

Annual Report 2019

University of Adelaide
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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. We would also like to thank all our collaborators: Monash University, RMIT University, The University of Melbourne, University of South Australia and The University of Adelaide.

ARC Graphene Research Hub

Contacts: Prof Dusan Losic, Director, Dr Jacqui McRae, Manager. Adminstrating organisation: North Engineering Building N206, North Terrace campus, The University of Adelaide SA 5005 AUSTRALIA
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Twitter: @ARCGrapheneHub

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ABOUT THE ARC GRAPHENE RESEARCH HUB

Background

The ARC Graphene Enabled Industry Transformation Hub was created to undertake graphene-related fundamental and applied research on graphene and 2D materials and their translation into enabling industry transformational solutions to tackle emerging industry, health, medical and environmental challenges

The Hub was co-funded (total \$6.5M) by the Australian Research Council as a partnership between 5 Australian universities and 5 industry partners to enable the development of a sustainable graphene-based industry in Australia.

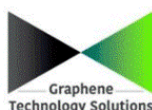
Graphene is one member of new 2-dimensional (2D) materials with exceptional properties and are recognised as the “Materials of 21st century”. Translation of research on developing these materials and their applications from academia to industry sectors there are several key challenges to be addressed:

- To develop scalable, low-cost and sustainable graphene manufacturing process and graphene supply chain
- to implement graphene quality control and international standards
- To ensure graphene materials are safe for use.

The Hub aims to address these challenges by bringing together a team of researchers and industry partners to develop graphene products and technologies that are needed across broad sectors such as mining, oil, energy, advanced manufacturing, defence and space industries, environmental and biomedical industries.



The ARC Research Hub for
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HUB MISSION, VISION AND VALUES

Mission

The Hub's mission is:

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

Vision

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

Values

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



DIRECTOR'S REPORT

The ARC Graphene Research Hub has completed our second year and we are delighted to present our research progress and outcomes from 2019.

In this year we continue to make substantial scientific impacts on translation of graphene research and delivery of new discoveries, innovation and outcomes to industry partners that will benefit broader industry and our society.

This is evidenced by many papers published, conference presentations, novel inventions and created IPs, new products developed and advances in technical readiness for commercialisation. The most outstanding examples are graphene fire retardants, sulphur-Li-ion batteries, corrosion protective coatings, membranes and adsorbents for water purification, graphene polymer composites and sensors. Their commercialisation and delivery to the market is underway and products may be available for market next year.

The ARC Graphene Hub has established a visible international reputation. We continue to Chair and organise the Australian-European Graphene workshop with the European Union Graphene Flagship which this year was successfully held in Helsinki, Finland. This continuing event is already making an impact on fostering international collaborations with Australian researchers and Australian graphene companies.

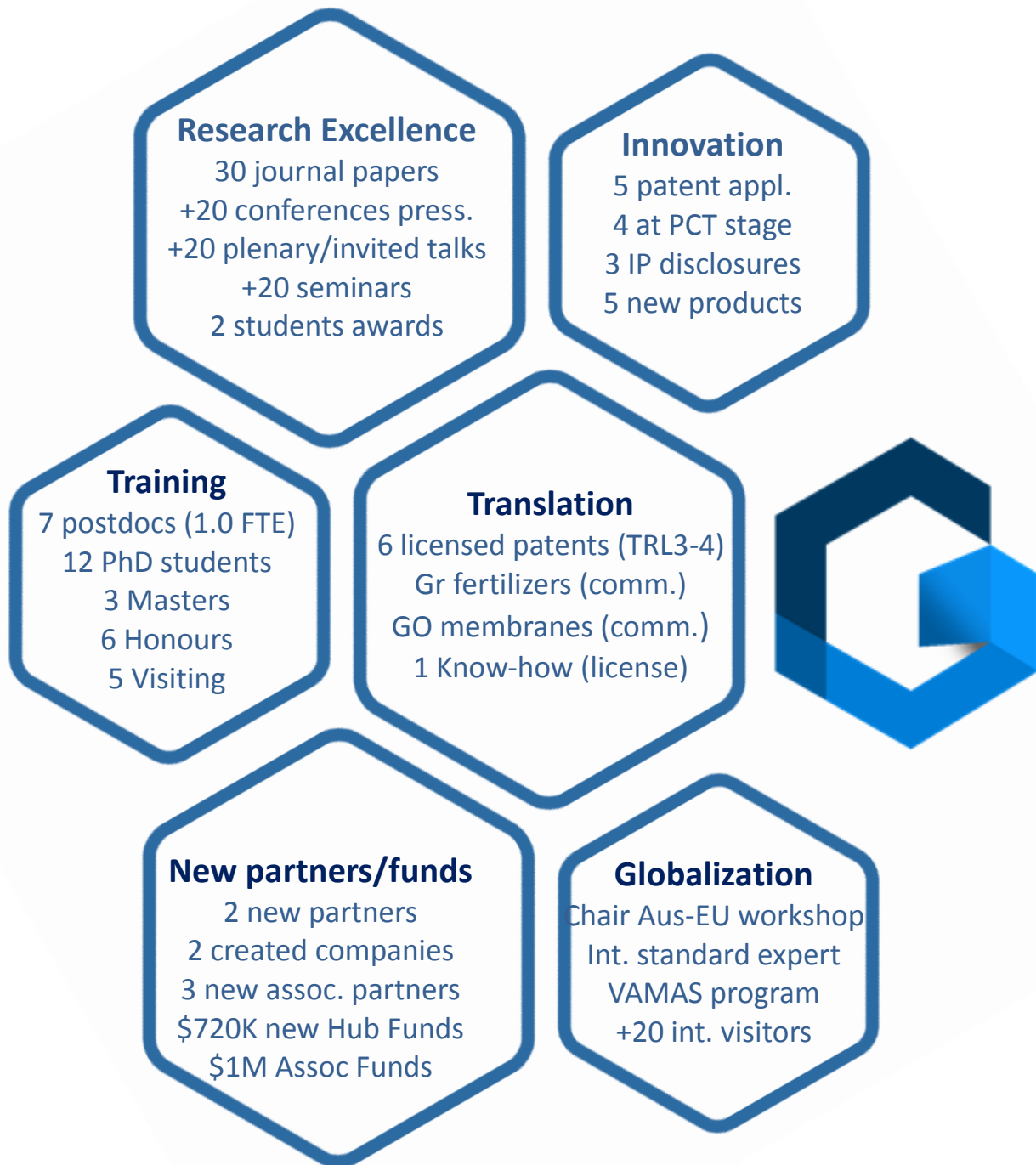
I would like to thank the ARC, our industry partners, the universities for their support, the Hub Management, research teams, and PhD students for their tireless and outstanding contributions.



A handwritten signature in black ink, appearing to read 'Dusan Losic'.

Professor Dusan Losic,
ARC Hub Director
Adelaide, February 2020

2019 HUB HIGHLIGHTS SUMMARY



RESEARCH TEAM AND MANAGEMENT

Executive Team

Directors



Prof Dusan Losic
University of Adelaide



Prof Mainak Majumder
Monash University



Prof Stan Skafidis
University of Melbourne



Dr Jacqui McRae
University of Adelaide

Hub Manager

Chief Investigators



Prof Namita
Choudhury
RMIT



Prof Christophe
Fumeaux
University of Adelaide



Prof Jun Ma
University of
South Australia



Prof Reza
Ghomashchi
University of Adelaide

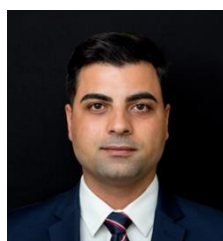


Prof Michael
McLaughlin
University of Adelaide

Partner Investigators



Craig McGuckin
First Graphene



Mohammad Choucair
Archer Materials



Uli Krueger
Cleanfuture Energy



Peter Voigt
NematiQ



Stephen Hunt
Graphene Technology Solutions

Postdoctoral Researchers



Dr Mahdokht Shaibani
Monash University



Dr Ramesh
Karunakaran
University of Adelaide



Dr Sharafat Hossain
University of Melbourne



Dr Tung Tran
University of Adelaide



Dr Farzaneh Farivar
University of Adelaide

Postdoctoral Researchers



Dr Grant Mathieson
University of Adelaide



Dr Md Julker Nine
University of Adelaide



Dr Tanesh Gamot
Monash University



Dr Nathan Stanley
University of Adelaide



Dr Ay Ching Hee
University of Adelaide



Dr Moussa
Mohammad
University of Adelaide



Dr Meysam
Mirshekario
Monash University

Visiting Researchers



Dr Qiulan Zhang
Nanchang University,
China



Dr Ana Pereira
University of Campinas,
Brazil

PhD Students



Ms Negar Mansouri
University of Adelaide



Mr Joynul Abedin
Monash University



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



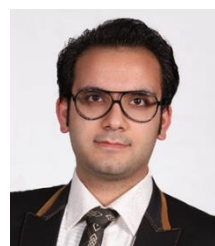
Ms Pei Lay Yap
University of Adelaide



Mr Kamrul Hassan
University of Adelaide



Mr Hadi Rastin
University of Adelaide

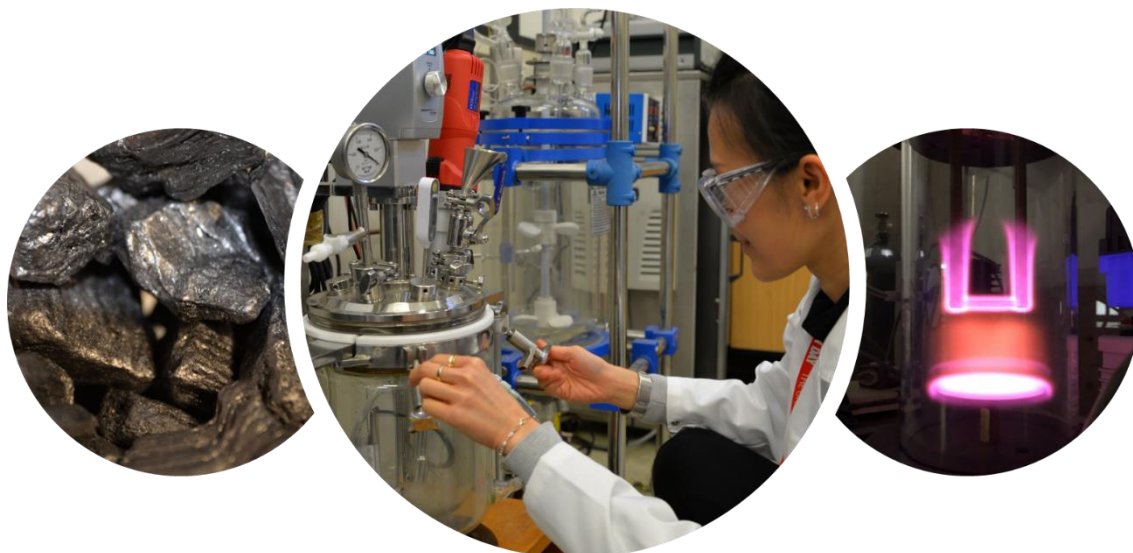
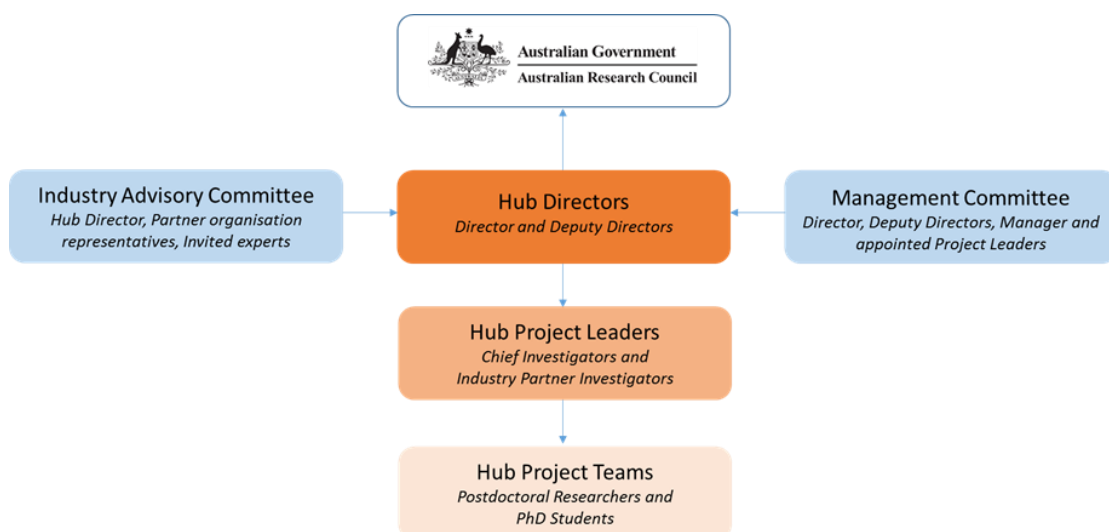


Mr Arash Mazinani
University of Adelaide



Ms Nicola Matulick
University of Adelaide

HUB GOVERNANCE



Industry Advisory Committee

Members of the ARC Graphene Research Hub would like to thank the contribution of the Industry Advisory Committee in 2019 for their contribution to the Hub's strategic direction.

- **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

COLLABORATION AND PARTNERSHIP



The Hub is very vibrant and productive research environment where +40 researchers including CIs, PIs, Postdoctoral researchers, PhD/Master summers students, and visiting researcher work together with Industry partners on a broad range of research projects. This interdisciplinary

team is strongly united with common goals pursuing innovative development of new cutting edge materials, products and technologies with commercial value for our partners and benefits for our society and building future industries.

HUB RESEARCH PROGRAM

The Hub's research program is structured into 3 sections combining an enabling fundamental research and graphene-enhanced product development for transforming industry applications to address of new graphene-enhanced products for social, environmental and economic benefit



The Hub includes 17 research projects divided into 3 Nodes addressing research topics:

Node 1: Fundamental Challenges

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

Node 3: Translation and Industry Adoption

Node 2: Products development and translation

- GO membranes for water purification (NematiQ)
- Adsorbents for heavy metals (GTS)
- Adsorbents for cleaning spilled oils (GTS)
- Adsorbents for soil remediation (GTS)
- Energy storage devices (SFE)
- Fire retardants paints (First graphene)
- Polymer composite (First graphene)
- Enhanced construction materials (First graphene)
- Biosensors and medical devices (Archer)
- Electro-magnetic shielding (DSTO assoc.)
- Graphene wearable antennas for high-volume applications
- Flexible electronics for biomedical application

HUB RESEARCH HIGHLIGHTS (Node 1): Fundamental Research

1.1. Graphene enabling research: production, properties, processing

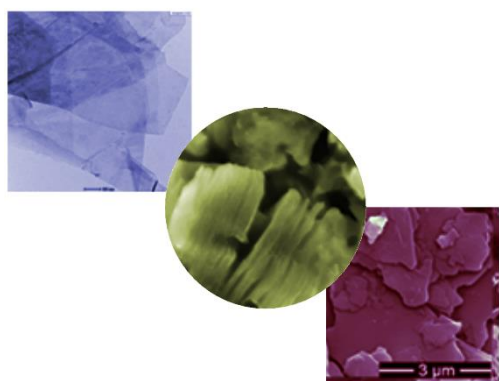
To implement graphene's exceptional properties into new products and to support existing Industry partner projects, Hub researchers developed several new methods for preparation and processing of graphene and 2D materials and discovered some new properties

New synthetic methods

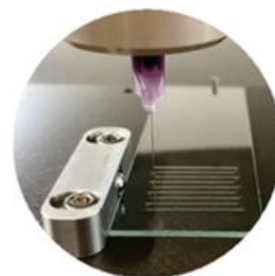
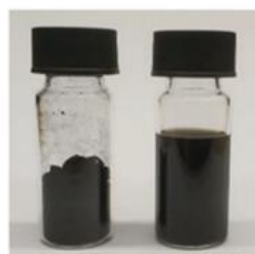
Several new methods for **scalable preparation of graphene and related 2D materials by improved and scalable exfoliation methods** were developed. Below: PhD student Pei Lay Yap working with Hub lab production unit reactors (**CI Losic**, UoA).



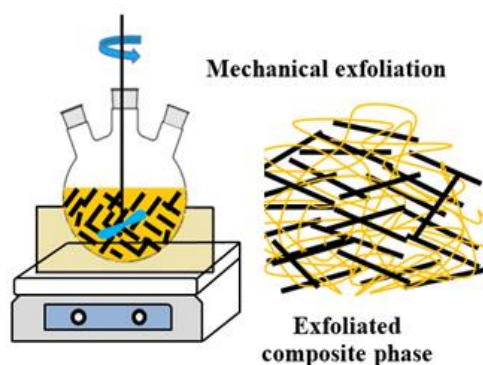
Several new **2D materials** with exciting new properties such as **hBN**, **MoS₂**, **Mxene**, **antimonene**, **phosphorene** are available for the Hub program. They will be combined with graphene materials for development of new products.



New method for **water dispersion of graphene materials** by their unique modification method was developed. This invention will open new applications for making graphene inks, 2D printing, sensors and wearable electronics (**CI Choudhury**, RMIT, Patent appl)



New method for **direct exfoliation of graphene** and polymers was developed by **CI Jun Ma** (UniSA Patent appl). This method will solve many problems of current processes for better graphene dispersion in polymer matrix.



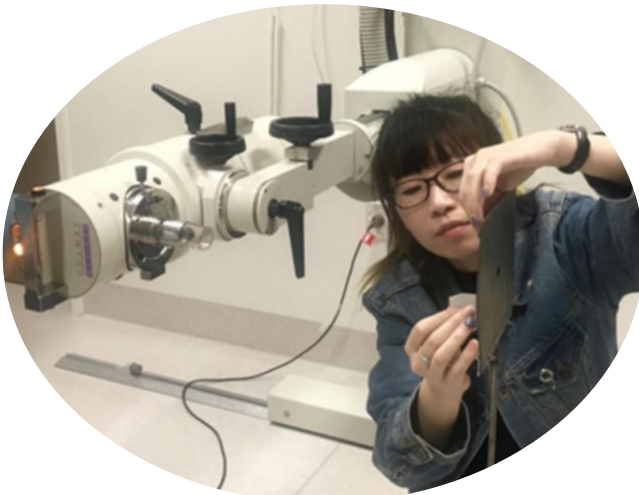
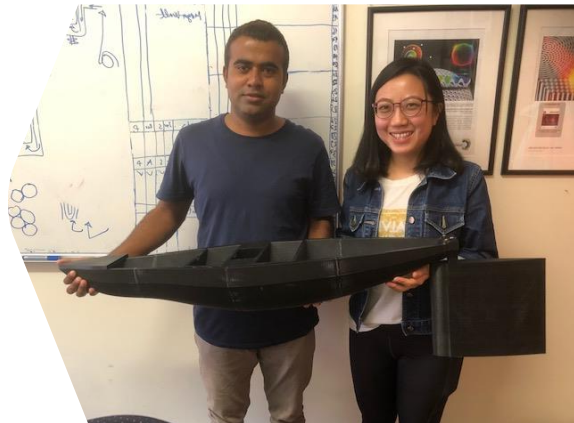
Testing samples

HUB RESEARCH HIGHLIGHTS (Node 1): Fundamental Research

1.1. Graphene enabling research: production, properties, processing

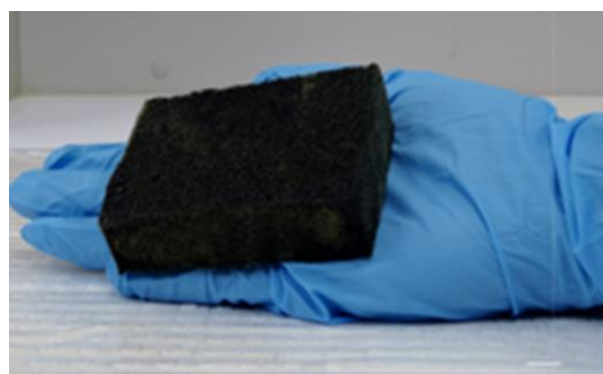
New concepts development and discoveries

New concept of surface drag-reduction and significantly reduced water friction were demonstrated with a graphene coating of a model boat. This technology may substantially reduce fuel consumption and CO₂ emissions for shipping and defence industries. Left: Dr Ay Ching and Dr Md J Nine with graphene coated boat (**CI Losic** UoA in collaboration with Dr Rey Chin, CEME)



New radiation shielding properties and concepts were discovered using graphene and 2D materials that opens enormous opportunities for disrupting existing shielding solution based on toxic lead. providing new applications in medicine, space and defence industry. Photo of PhD student Le working with X-ray instrument (**CI Losic**, UoA, with Alex Santos, Physics/RAH, Patent appl.)

New sound absorption properties and concepts are discovered for graphene lamella structure made self-assembled in matrix of commercial polyurethane or melamine foams. The improving of foam sound absorption performance over 60% and making them fire and moisture resistive and robust. Patent protected and licensed with product development in progress. (**CI Losic** in collab with A. Zander, B. Cazzolato et al UoA, ME)



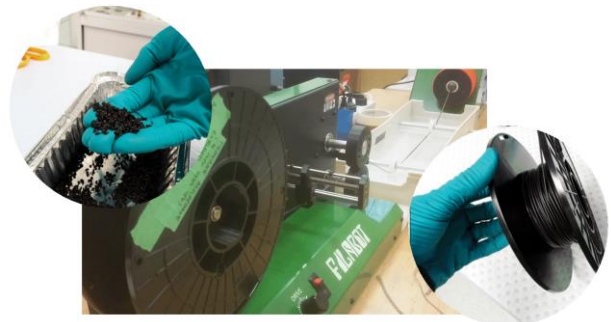
HUB RESEARCH HIGHLIGHTS (Node 1): Fundamental Research

1.1. Graphene enabling research: production, properties, processing

To implement graphene's exceptional properties into new products, Hub researchers developed several platform technologies to incorporate these materials into additive manufacturing for direct and low-cost production and prototyping of new functional 2D or 3D printed devices. The Hub developed several key platform technologies for fabricating custom-made graphene inks, and filament for 2D and 3D printing for manufacturing of broad range of products including sensors, films, antennas, conductive elements, electrical circuits and wearable electronics.

Graphene and 2D materials inks

Developed ink formulation technologies for several graphene and 2D materials with different properties that can be used in commercially available ink-jet printers and other common printers for prototype- and small-scale device manufacturing. These formulations are the first step to enable faster translation of these materials into new product development. Conductive inks are a >\$20 billion market.

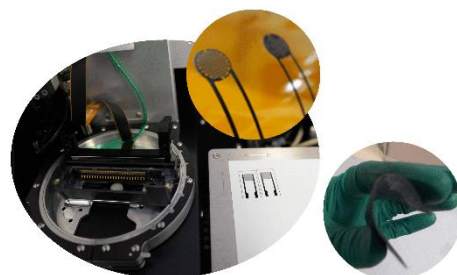


Graphene filaments for 3D printing

Developing 3D filaments and additives for soft, hard and metal 3D printing with graphene and 2D materials combined with polymers, metals and inorganics is another important area for Hub researchers with several promising outcomes. This development is another important platform technology that will provide faster translation of these materials and their direct use for low-cost and fast manufacturing of new products and devices. Among them is graphene conductive filament for 3D printing which is in high demand on global market and only 3 current producers.

Prototyping and product development

Graphene inks and filaments were extensively used as a platform technology for Hub Industry and associated partners for developing a broad range of new products and devices, including new transparent and conductive coatings, LEDs, protective coatings, chemical- and pressure-sensors, antennas, electrodes, shielding elements and wearable electronics, and conductive composites.



HUB RESEARCH HIGHLIGHTS (Node 1): Fundamental Research

1.2. Graphene Standardization and Characterization

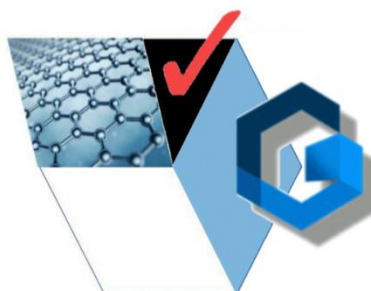
Standardization and characterization of manufactured bulk graphene materials is one of biggest challenges for future graphene industries. The Hub team is extensively working on developing graphene characterization methods and quality control systems in collaboration with national and international standardization organizations.

Standardization and Quality Control

The Hub team established the quality control (QC) system for characterization of graphene bulk materials combining +20 analytical methods including TEM, SEM, EDAX, AFM, XPS, XRD, Raman, XRD, TGA, BET and PSD. Some of these methods are specifically adapted for graphene and 2D materials analysis. This developed QC system is used to support Hub projects and industry partner needs and is available for other Australian and International companies.

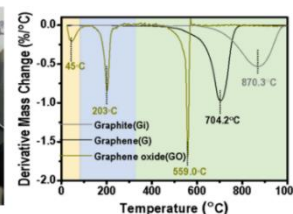


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Thermal gravimetric method (TGA) was developed by **CI Losic's** team (UoA) into an advanced analytical QC tool able to confirm purity and quality of bulk graphene materials. This method is in the process of international validation and will be translated into an international standard for universal use in graphene industry.

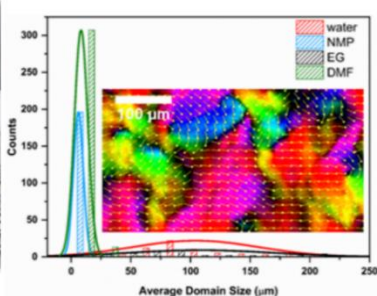
International Standardization



The Hub's work on graphene QC problems has been recognized by invitations (**CI Losic**, UoA) to be involved as the member of National and International (ISO, VAMAS) and the technical experts group working on development of standards and methods for graphene and related 2D materials.

New testing method developed

New method for characterization of graphene oxide (GO) based on **polarized light microscopy** able to determine number of layers and defectiveness of GO was developed by **CI Majumder** (Monash). Below: microscopy and typical image of GO sheets with different thicknesses.



HUB RESEARCH HIGHLIGHTS (Node 1): Fundamental Research

1.3. Environmental and Health impact of graphene materials

The Environmental and Health impacts of graphene materials and their products are the topics of the highest scientific priority. The Hub researchers lead by CI McLaughlin (UoA) are doing pioneering work on ecotoxicology of graphene materials and their degradation behaviour in soil and environment providing valuable contribution to this field.



Ecotoxicology

One of the first studies on ecotoxicology of graphene oxide showing influence of different concentrations of GO on algae (*Raphidocelis subcapitata*) and a shrimp (*Paratya australiensis*) was published in Chemosphere <https://doi.org/10.1016/j.chemosphere.2019.125640>. The team developed new ecotoxicological method for these assessments not available before.

Addressing challenges in providing a reliable ecotoxicology data for graphene-oxide (GO) using an algae (*Raphidocelis subcapitata*), and the trophic transfer consequence of GO-algae aggregates

Marijana Markovic^{a, b, *}, Ivan Andelkovic^a, Jeremiah Shuster^{a, b}, Leslie Janik^b, Anupama Kumar^b, Dusan Losic^d, Michael J. McLaughlin^{a, b, *}

Show more

<https://doi.org/10.1016/j.chemosphere.2019.125640>

Chemosphere

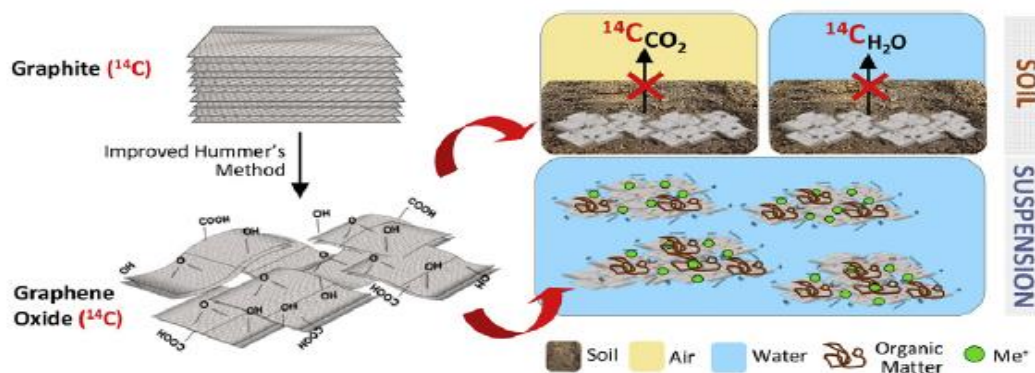


Highlights

- Ecotoxicology of modified graphene-oxide (GO) was assessed using an algae.
- The adverse effects of GO-algae aggregates were estimated using a shrimp.
- Characterization, quantification and suspension stability of GO were addressed.
- Specific surface area and the shape of GO were affected by the composition of media.
- Osmium helped to avoid bias and gave a reasonably good images of algae sections.

Graphene degradation in soils

The second study by this team was to use ^{14}C labelled graphene oxide to explore its degradation in soil and uptake by plants. The study published in Chemosphere <https://doi.org/10.1016/j.chemosphere.2019.124558> provides a highly valuable information about aggregation behaviours graphene and their degradation in soil not explored before. This ongoing research attracted a high scientific attention but we have limited resources to perform full scale study looking for more funding in future.



HUB RESEARCH HIGHLIGHTS: News from Hub Industry partners

- First Graphene Pty. Ltd (FGR)

*First Graphene Pty Ltd is recognized as a world leading graphene company. This standing is built on extensive R&D investment and collaboration with Universities. Their collaboration with UoA started in 2015 with successful development of new graphene manufacturing process. The company lead by **CEO and PI McGuckin** is actively working on Hub program for development of new products (fire retardant, polymer composites and construction materials) and have support for their graphene certification and QC needs.*



First Graphene – key milestones

Graphene industrial manufacturing process is established in Perth based on green and unique electrochemical process developed in collaboration with UoA team (**CI Losic**). With graphene production capacity of 100t/y it is now one of the most reliable global suppliers of high quality graphene materials.



Graphene materials certification is completed in Australia (NICNAS) and International (RICH) with rights to export these materials world-wide. FGR is one of few companies that globally certified their produced graphene materials.



Fire retardant paints that FGR is developing with Hub program is in the final stage of formulation and testing making significant progress toward future commercialization.



Graphene-enhanced safety boots and mining wear lining are two new products under development from polymer composite project.

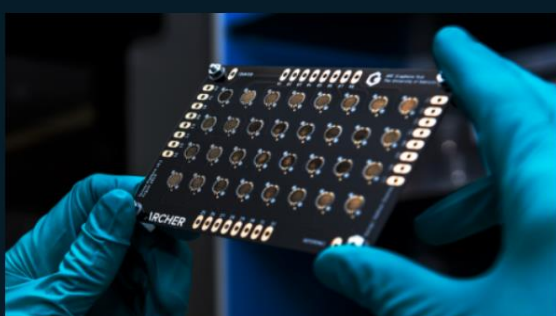


HUB RESEARCH HIGHLIGHTS: News from Industry partners

- Archer Materials Pty Ltd

*Archer is one of first graphite exploration company started graphene research and collaboration with UoA (2014) with continues investing in graphene and advanced materials development as part of their long term commitment on growth plan. Hub researchers (CI Losic, UoA) working with Archer's Materials **CEO and PI Choucair** on development of advanced materials underpinning biosensor technology and health care diagnostics.*

ARCHER



ADVANCED MATERIALS

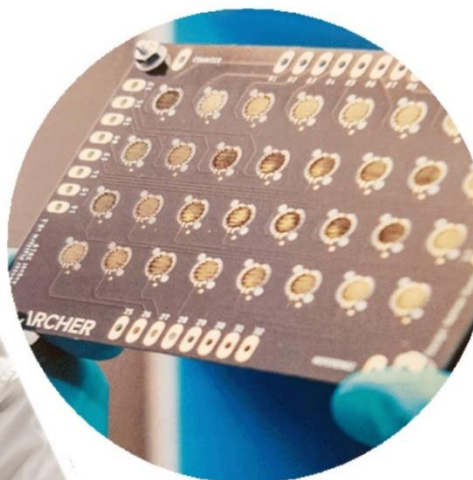
Archer has a diverse advanced materials inventory, strong intellectual property, world-class expertise, and access to over \$300 million of R&D infrastructure.

ADVANCED MATERIALS TO UNDERPIN TECHNOLOGY



Hub researcher **Dr Nathan Stanley** (below) working on developing graphene inks for Archer project and using Hub 2D printing technology for low-cost fabrication of biosensing devices and platforms for personalised diagnostics. This

development is currently in progress with the completion of the first proof-of-concept graphene-based biosensor prototype (below) and will be pursued in future in collaboration with Archer's team.



HUB RESEARCH HIGHLIGHTS: News from Industry partners

- Graphene Technology Solutions (GTS)

*Graphene Technology Solutions (GTS) is one of our newest industry partners to join the Hub program this year with significant investment in research and development across several areas including water purification, soil remediation and protective coating using graphene-based technologies. This Adelaide-based company lead by **CEO and PI Hunt** involves local investors with a long-term commitment for growing high-tech graphene company is **created with Hub support** based on a strong collaboration with the UoA (CI Losic) graphene research.*



HUB RESEARCH HIGHLIGHTS: News from Industry partners

- NematiQ

NematiQ is a new company that recently joined the Hub with a commitment to commercialising graphene-enhanced membranes for water purification that were developed by the Hub's Monash team (CI Majumder). NematiQ CEO and PI Voigt are very excited to work with the Hub team on clean water solutions which is one of the top global problems. This the second company created from Hub programs



Graphene membrane manufacturing

The Hub's Monash team (CI Majumder) developed the first scalable graphene membrane manufacturing process and demonstrated pilot-scale production of the membranes (pictured left). This process is now being used for industrial scale production in Melbourne.

These new graphene membranes will be applied for broad range of water treatment applications including drinking and industrial water treatment.



Above: Photos of printing instrument with manufacturing of graphene oxide membranes for water filtration

HUB RESEARCH HIGHLIGHTS (Node 2): Products development

Addressing significant global problems (reliable, renewal energy)

The Hub is committed to developing novel technologies for a sustainable renewable energy industry

Longer-life batteries

A cheap, high-performance and longer-lasting battery has been developed by the Monash team in collaboration with industry partner, **Cleanfuture Energy**.

This new lithium-sulfur battery has the potential to improve the performance of electric vehicles and provide storage options for solar power.

Thermoelectric alloys for efficient renewable energy devices

Mixing graphene nanoplates into thermoelectric alloys affects the robustness of the material. The team at the University of Adelaide showed that the addition of graphene nanoplates can enable the thermoelectric alloys to withstand thermo-mechanical shocks. These results may improve

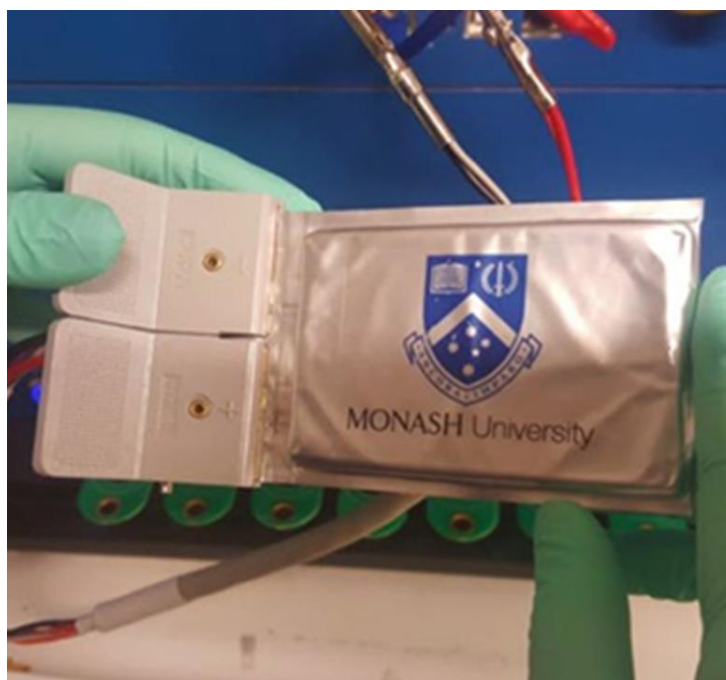
the efficiency of renewable energy resources such as in solar heat exchangers.

Graphene-based conductive hydrogels

A flexible solid-state supercapacitor was developed by the team at the University of South Australia. Electrochemical performance of this new hydrogel supercapacitor surpassed that of many previously reported solid-state supercapacitors.

These results demonstrate the potential of conductive polymer composite hydrogels to combine excellent performance with greater mechanical resilience.

Technical readiness: TRL3, **Outcomes:** 1 patent and 1 paper



Above: Prototype of pouch cell of new lithium-sulphur battery (CI Majumder, Monash team)

HUB RESEARCH HIGHLIGHTS (Node 2): Products development

New generation of Fire protective coatings: Addressing significant global problems

*Fire disasters are one of world biggest problems costing global economy trillions \$ with significant loss of properties and lives. The Australia's bush fires are extremely catastrophic costing economy +\$20 billions/y with thousands houses are hundreds lives lost every year. The Hub research team lead by CI Losic and FGR industry partner are very dedicated to address this problem by developing **new generation of graphene-based fire-retardant paints**.*



New Fire protection concept: A new Fire retardancy concept based on oxygen barrier properties of graphene was discovered by **CI Losic's** team (UoA) and translated into a new graphene paint formulation and licensed to a Hub industry partner (FGR). Current FR paints are based on toxic halogenated materials that have catastrophic impact on the environment and human health. The new paint was found to

be more efficient and provide several new properties not achievable with conventional FR paints. **Dr Md Julker Nine** is a key Hub researcher progressing this development with FGR team.

Technical readiness: TRL4, **Outcomes:** 2 patent, 3 papers, 5 conferences



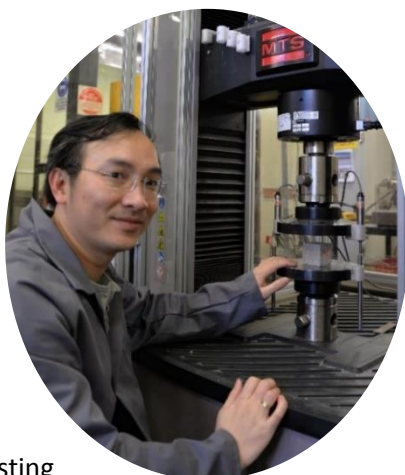
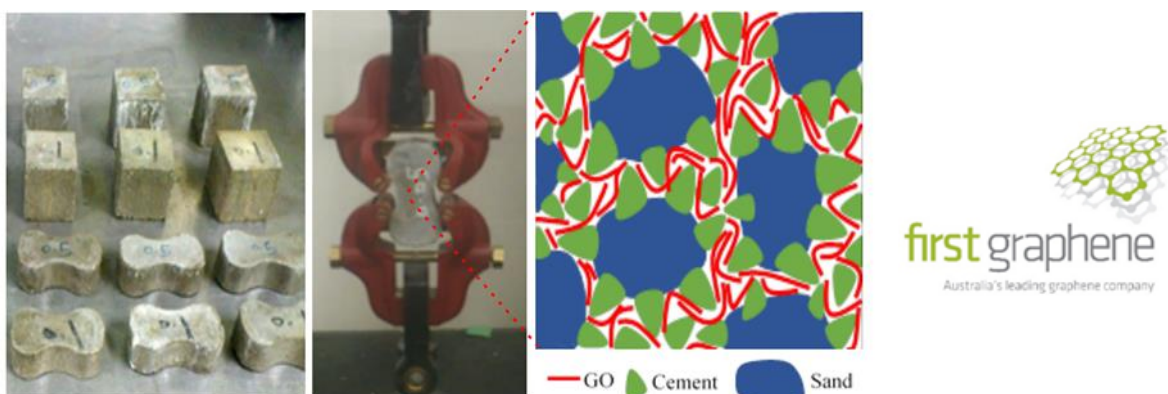
HUB RESEARCH HIGHLIGHTS (Node 2): Products development

Improving Construction Materials: Addressing global problems (CO₂ emission)

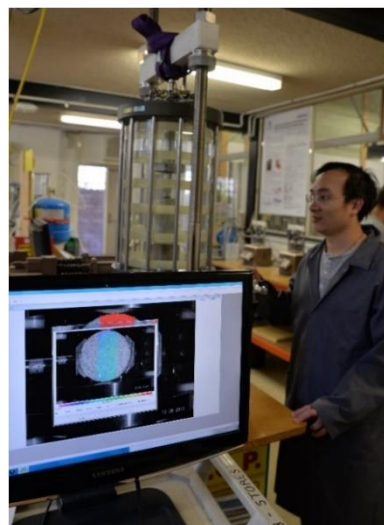
Concrete is the most widely used man-made material in existence and is the most-consumed resource on the planet after water. Unfortunately concrete is not an environmentally friendly material, either to make, or to use, or even to dispose. Concrete contributes about 8% of the world's carbon dioxide (CO₂) emissions and impacts on climate change. Hub team (CI Losic, UoA) with FGR partners and their collaborators in concrete industry are working on using graphene to improve the performance of cementous construction materials and reduce their negative environmental impacts.

Our study published in several papers showed that addition of graphene at very low concentrations can significantly enhance the tensile and compressive strengths of concrete. In addition graphene can also improve durability, fracture and water resistance, and also provide unique sensing properties to monitor internal cracks and deformation. FGR manufactures graphene with the largest sized sheets which have excellent performances in concrete. This type of graphene is under exploration for several Hub projects.

Technical readiness: TRL3, **Outcomes:** 5 papers, 3 conferences



PhD student Van Dac testing graphene/cement composites using FGR graphene with CEME facilities at UoA



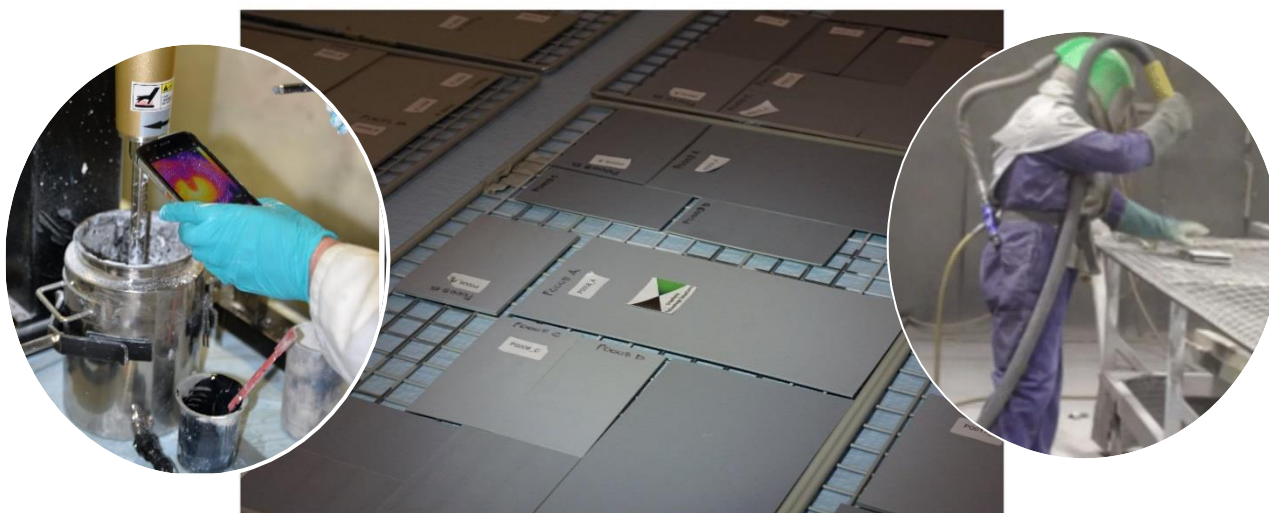
HUB RESEARCH HIGHLIGHTS (Node 2): Products development

New generation of anti-corrosion coatings: Addressing significant global problems (corrosion)

Corrosion costs are globally above \$2.2 trillion per year (3%GDP) and in Australia, \$12 billion. Currently-used paints with protectants and inhibitors are less effective and often toxic causing significant environmental problems. Graphene has excellent barrier properties and is recognized as potential solution for developing a new generation of anticorrosive coatings. The Hub research team lead by **CI Losic**, UoA and GTS

are working together on associated Hub project to address this problem by developing **new graphene anti-corrosive paints**.

Technical readiness: TRL2-3, Know-how



Dr Grant Mathieson, UoA inspecting the first batches of sprayed samples of developed anticorrosive graphene paint. The team is performing extensive mechanical, weathering and environmental testing compared with benchmark paints

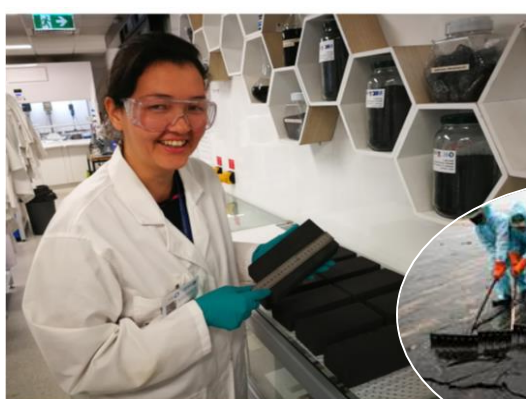
HUB RESEARCH HIGHLIGHTS (Node 2): Products development

New generation of environmental adsorbents: Addressing significant global problems (Environmental pollution)



Spilled Oil removal: Spilled oil has significant and immediate economic, social, and environmental impacts. Local people lose their livelihoods as fisheries and tourism areas are temporarily closed and tens of thousands of marine animals and plants are killed or harmed. The cost of cleaning up is enormous dominated by physical removal of oil, burning or chemical methods, which are not satisfactory. To address this

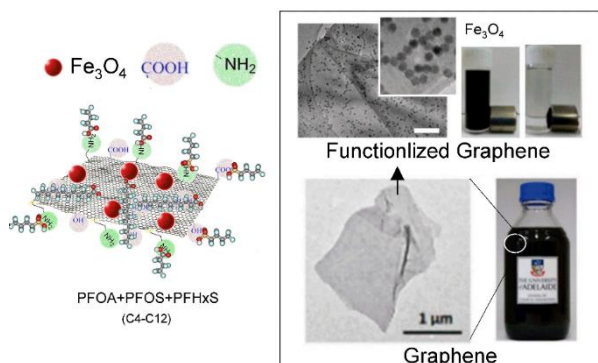
problem the Hub team (CI Losic, UoA) with industry partner GTS are developing new graphene-based technology for efficient removal of spilled oil. The concept is based on developing super-hydrophobic foam with high surface that adsorbs a large amount of oil. The oil is then easy to remove and recycle. **Technical readiness: TRL4, Outcomes: 2 j. papers**



Dr Frazaneh Fravivar, UoA with prepared graphene foams for spilled oil demonstration experiment that is scheduled in March 2020.

Soil Remediation: Per- and Polyfluoroalkyl Substances (PFAS) contaminants called “chemicals forever” are currently one of the most concerning global environmental problems, due to their environmental and public health impacts arising from their widespread global distribution, high persistence, bio-accumulative properties and carcinogenic nature. Their remediation from

water, soil and other environmental system is extremely challenging because of +500 different PFAS types, with different structures and high stability. The Hub team (**CI McLaughlin/ CI Losic**, UoA) working with GTS on developing new graphene based adsorbents for efficient removal of PFAS from waters and soils.



HUB RESEARCH HIGHLIGHTS (Node 2): Products development

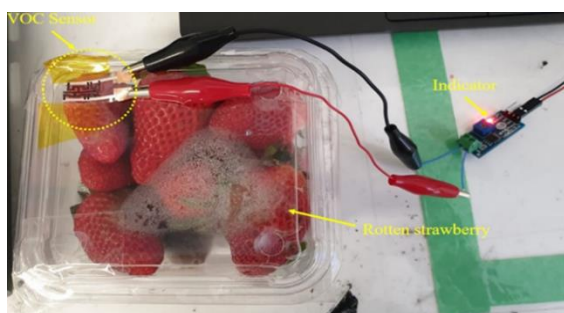
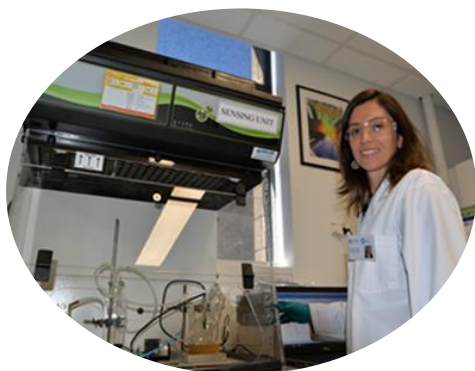
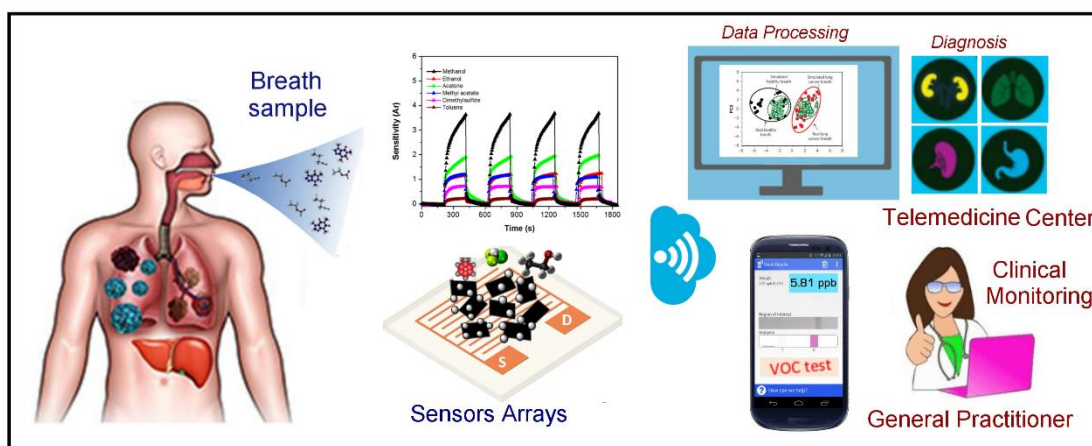
Printable sensors for medical, environmental and food control

The Hub researchers are developing several sensing platforms for broad-range of applications using low-cost printed graphene and 2d materials.

Sensing breath biomarkers for medical diagnostics

The Hub team (**CI Losic**) with collaborators is developing new graphene-based sensing platform fabricated by 2D printing for detection of cancer biomarkers from breath. The aim is to develop non-invasive personalised medical

diagnostics with series of wireless sensor that can be connected to smart phone and the internet. The concept is in early stages of development based on developed graphene inks and 2D printing technology for sensing +10 cancer biomarkers. Future collaborations with industry partners are need for further development of this technology.



Chemical sensors for environmental and safety control

Chemoresistive graphene-based sensors with high sensitivity to a series of volatile organic compounds (VOC) were developed showing considerable potential for their applications as wearable and wireless sensing for environmental control, mining and defence industry.

Chemical sensors for food packaging

Sensors have been developed as PhD work by **Kamrul Hassan** (UoA) that can detect the chemicals produced in the early stages of food spoilage. These graphene-based sensors can potentially be incorporated into smart food packaging that can be used to monitor food freshness. Left: Sensor used to detect early stage of spoilage in a packet of strawberries.

HUB HIGHLIGHTS (Node 3): Licensing, translation, commercialization

Hub researchers have licensed 6 technologies in total from our graphene research (5 UoA, 1 Monash). One outstanding example is successfully licensing of UoA patented invention of Hub researchers **CI McLaughlin** and **CI Losic** team on the development graphene-based fertilizers to one of world largest fertilizers company in USA.

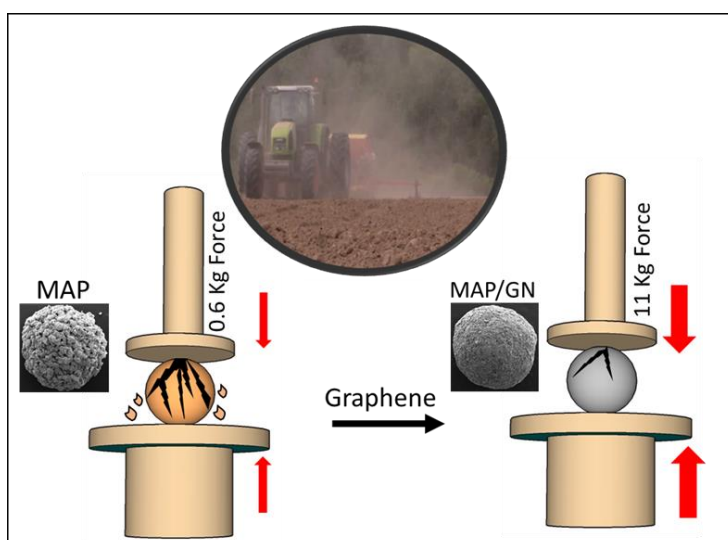
New generation of nutrients delivery

New concept was discovered using graphene materials as carriers for micronutrients delivery which provides a long sustainable release and improve properties of soil.



Improving properties of conventional fertilizers is shown by graphene coating and additives that improves their strength and

mechanical properties, provides slower release and proved better performances with enhanced crop production

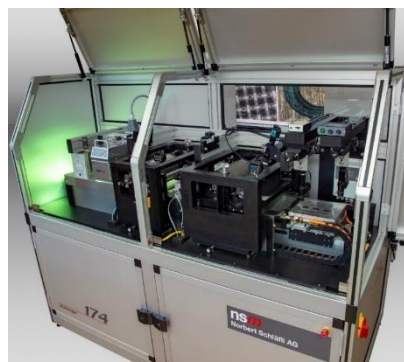


Above: The concept of improving mechanical properties of commercial fertilizer (left) and fertilizer pallets before and after graphene coating (right).

HUB HIGHLIGHTS: Building new capabilities and infrastructure

This year Hub researchers across several universities received several new facilities that substantially built their prototyping, fabrication and testing capacity for processing graphene materials, printing devices and their characterizations.

Multifunctional printing: Monash (CI Majumder) received ARC LIEF grant (\$1.1M) for a high-precision multifunctional printing, and coating system for the development of printed electronics and multiple printed functional devices. This system opens new dimensions for the development of printed electronics and sensors for Hub researchers and across Australia.



New testing method development. New salt-spray corrosion system for testing of graphene paints and coating was purchased by Hub partner (GTS). This instrument will test environmental stability and robustness of developed anti-corrosion paint and coatings required by international standards.

Accelerated weathering tester. New QUV weathering tester that reproduces the damage caused by sunlight, rain and dew by exposing materials to alternating cycles of UV light and moisture at controlled, elevated temperatures is established at UoA (GTS project). It simulates the effects of sunlight using special UV lamps, dew and rain with condensing humidity and/or water spray providing the simplest and most reliable weathering testing.



Plasma powder coating: New plasma system for modification and functionalization of graphene and 2D material powders is purchased at UoA that will be used for many projects across the program to improve performance of developed products and devices.



HUB'S RESEARCH LIFE, COLLABORATION AND COMMUNICATION

The Hub program established a well-organized communication system to allow collaboration to freely flow across several universities with extensive involvement of PhD students, postdoctoral researchers, CIs, international collaborators, PIs and technical staff from Industry partners.

Hub workshop every year: At this Hub workshop where all members, Industry partners and collaborators are coming together to present and discuss their research and future ideas and collaboration, with lab tours and demonstration, posters, brainstorming panels.

Workshop highlights:

+40 delegates, 3 sessions, 2 keynote, 16 oral presentation, 8 posters, 1 panel discussions and 2 lab tours, joined barbeque (social event)

Satellite Hub workshops (video conference):

Two meetings per year organized by postdoctoral researchers and PhD students to discuss their projects and exchange ideas. This was very successful meeting that generates many joined papers and several new project ideas.

Team collaborative meeting:

This is most common communication way for monthly face to face or phone meeting with different research teams, CIs and industry partners



Poster showing highlights from 2019 Hub workshop held in Adelaide

HUB GROWTH, NEW PARTNERSHIPS AND FUTURE

The Hub team continues to grow with new Hub partners, new Hub funding, new associated partners with new external funding, new team members and facilities.

New Hub Partners and Funding

This year the Hub welcomed two new partners: **GTS and NematiQ** working on 3 new projects. This new partnership will bring total \$720K in new funding over the next 3 years to support these projects.

As part of the Hub's growth strategy we managed to engage few more industry partners working on specific contract research projects (graphene characterizations, batteries, protective coatings) outside the Hub program. Contract research has been conducted with several companies including GTS, Volta and MRC at UoA. These new research projects generated ca \$1 million of additional research funding and considerably improved the Hub team's research capabilities providing new funds for purchasing new facilities.

Linkage and other grants

CIs applied for ARC LP and LIEF grants with two successful outcomes. **CI Majumder** at Monash University successfully LIEF bid for a new \$1.1M Integrated Functional Printing Facility for Advanced Materials Technologies at Monash University. **CI Jun MA** was successful with LP grant and **CI Fumeaux** with DST (CERA) grant.

New team members

The Hub welcomed new Hub Manager **Dr Jacqui McRae** who started her role in June. She made significant improvements in the Hub operations that we will see the results of in following years. New postdoc (women only application) **Dr Farzaneh Farivar** joined to start the environmental remediation project. Purna Bdr. Samal started a PhD into wireless antennas and several new masters received admission and will join in 2020.

Strategic business opportunities

The Hub has entered the third year of the five-year program and the Hub Management and

Industry Advisory Committee started exploring opportunities to grow this graphene program beyond the Hub.

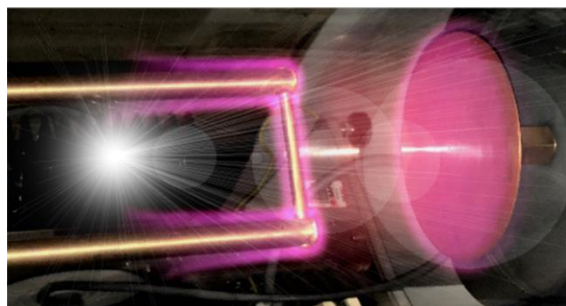
The following business opportunities were created and progressed:

- New spin-off company, NematiQ, has been formed in a collaboration with Ionic Industries from **CI Majumder's** IP (Monash)
- A Strategic Partnership Agreement with Hub Partner, GTS to facilitate the licensing and commercialisation of Hub-developed technology from **CI Losic's** IPs (UoA).
- Potential partnerships and new research contract work with other research groups including CSIRO, ANSTO, and DSTO.

The Hub has also been contacted by many industry, venture capitalists and investors keen to invest in translation and commercialization of R&D and IP from the hub. These potential partnerships could further enhance research outcomes and industry transformation and will be the Hub focus in 2020.

The Hub Future

The Hub 5 years program and funding is finishing for 2 years and in 2020. We plan to have extensive conversations with key stakeholders about Hub future to make the decision to apply for another ARC Research Hub or explore another options



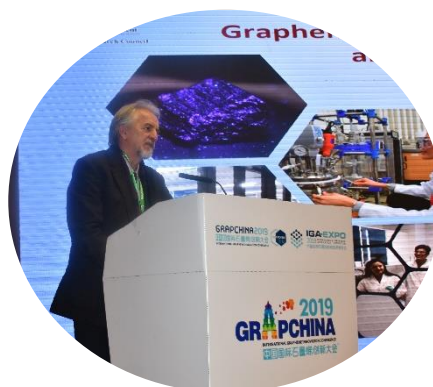
INTERNATIONAL ENGAGEMENT AND COLLABORATIONS

The Hub's international reputation significantly increased in 2019 with invitations to several key international graphene conferences (Grapchina and EU Graphene Flagship) as workshop organizers, session chairs, plenary, keynote and invited speakers, panel discussions and industry exhibition. These events were used to promote the Hub program and foster new collaborations.

Partnership with CGIA (China)

China is one of the leading countries in graphene research and graphene industrialisation with +3000 established companies and very strong R&D programs. Hub Director **CI Losic** established a very strong collaboration with China Innovation Alliance of the Graphene Industry (CGIA) who is the organiser of Grapchina, the world's largest graphene conference.

This year at Grapchina 2019 in Xian, the Hub presented at several sessions on international collaboration and industry cooperation. CI Losic gave a plenary lecture at the conference and a keynote lecture for the Standardization session. This important meeting discussed problems in graphene quality and characterization and included a special panel discussion with Nobel prize winner Andre Geim and graphene leaders from China and EU flagship about strategies for international collaboration.



Qingdao and Shanghai as well as universities (Xian, Qingdao, CAS, Linyui) and gave +10 scientific seminars and presentation about the Hub program and collaboration opportunities. Several offers have been received to license Hub technologies and opening joint companies and ventures in China.

The Hub International promotion

China: To promote the Hub and initiate new collaboration in China, Hub Director CI Prof Losic visited several graphene companies in Xian,



EU Graphene Flagship: EU Flagship is world leading graphene concentrations with 1BN Euros investment. The Hub team, including Director, Hub Manager and **PI Hunt** (GTS) as part of the 2nd Annual Australian-EU workshop held in Helsinki during Graphene Week met with many EU-based graphene companies and research leaders. The Hub Director was involved on EU Graphene Flagship industry forum and panel discussion about major challenges of emerging graphene industry and translation of graphene research.

INTERNATIONAL ENGAGEMENT: 2nd Australian-European Graphene Workshop



The 2nd Graphene Flagship EU-Australia Workshop on Graphene and related 2D materials

23- 24 September 2019

Helsinki Scandic Marina Congress Center

Katajanokanlaituri 6, 00160 Helsinki, Finland

23rd September - Nordia, 2nd floor; 24th September

Chairs: Dr Ken Teo (UK), Prof Dusan Lolic (Australia)

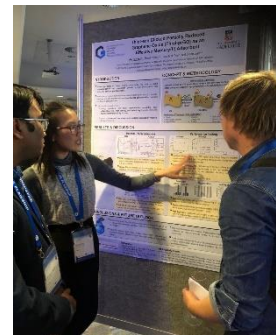


The second Australian-EU Graphene Workshop organized by EU Graphene Flagship and ARC Graphene Hub was held in Helsinki, 23-24 Sept 2019. The workshop gathered about **40 participants with 15 speakers (9 from Australia and 6 from Europe), including 4 from industry.** The workshop addressed topics of graphene production and functionalization, composites, filtration, energy, sensors, commercialisation and certification.

The workshop opened many useful discussions about the importance of certification and quality control of graphene materials and confidence for their adoption in the market. The workshop enabled new collaborations with EU Graphene

Flagship members including, NPL (UK), Manchester University (UK), UCLA (USA) CNRS (France), Thales (France), and CAS (China). The format and topics of the 3rd workshop to be held in Australia (Melbourne) will include solving common challenges and bringing closer collaborations between Australia and the EU.

The Australian delegates spent one day on lab tours visiting Helsinki and Aalto University and VTT Technical Research centre Finland and had opportunity to explore collaboration with researchers in this country. Hub presenters included PI Hunt (GTS) and PhD students (**P.L. Yap, J. Abedin and T. Foller**).



CEO EU Graphene Flagship and Hub Director

INTERNATIONAL ENGAGEMENTS AND LEADERSHIP

The Hub is recognized as one of key international contributors in the field of graphene and 2D materials standardization. This is demonstrated by CI Losic's invitations to give plenary/invited lectures on this topic (China, Australia), organise seminars, join Australian Standards and ISO experts and International graphene certification teams, and to lead an international VAMAS validation of graphene characterization methods.



International Graphene standardization initiative

Several international experts meetings on graphene standardization were held in China and Australia with the Hub representative (CI Losic) discussing implementation of ISO standards on graphene materials, certification of graphene materials and graphene producers, problems with graphene quality and characterization methods.



CI Losic invited lecture and discussion panel at International Graphene Standardization forum

VAMAS International inter-laboratory validation of graphene standards

The Versailles Project on Advanced Materials and Standards (VAMAS) was established by economic summit in 1982 held at Versailles by the Heads of State of the G7 group. The aim is to provide the technical basis for harmonisation of measurement methods, leading to best practices and standards.

The Hub successfully participated in the **VAMAS Projects and Interlaboratory Comparisons of Raman method** for characterization of graphene materials led by National Physical laboratory (UK) Dr Andrew Pollard and completed a report on testing provided standards samples. Our lab was selected among 20 leading graphene labs world-

wide to participate in this Program. Results will be published in a journal paper and as VAMAS and ISO reports.

The Hub was also invited to **lead VAMAS Projects and Interlaboratory Comparisons validation program on Thermal Gravimetric Analysis (TGA)** for characterisation of bulk graphene materials. The aim is to validate the methodology for characterising graphene bulk materials (graphene, rGO and GO powders) using TGA and determine the uncertainties associated with the measurement and data analysis. The project will start in March 2020 and with participation of 20 leading graphene labs from 5 continen

TRAINING FUTURE EXPERTS AND LEADERS

The Hub program provides an excellent research environment and an ideal opportunity for research training for postdoctoral researchers, PhD, Honours, summer and visiting students.

Hub's Students and postdocs received valuable research experience and mentoring working in emerging field of 2D materials with world leading scientists and industry partners to become future experts and research leaders.



The Hub training includes:

- 8 Postdoctoral researchers (1.0 FTE)
- 2 Postdoctoral researchers (casual)
- 14 PhD students
- 5 Masters students
- 5 Honours students
- 4 summer students
- 2 Visiting Int. senior researchers (Brazil, China)
- 2 Visiting Phd (China, Pakistan) both completed PhD
- 2 Completed PhD students
- 3 Completed Masters students

Awards

- Best PhD student in SA Award from Malaysian government (Pei Lay Yap)



Hub Honours students in 2019 at Ingenuity Showcase their research projects to high school students

WOMEN IN GRAPHENE: INCLUSION AND DIVERSITY

The Hub women inclusion and diversity we believe is one of key factors making this program more productive and efficient

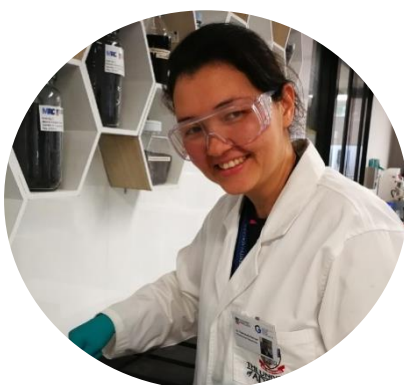
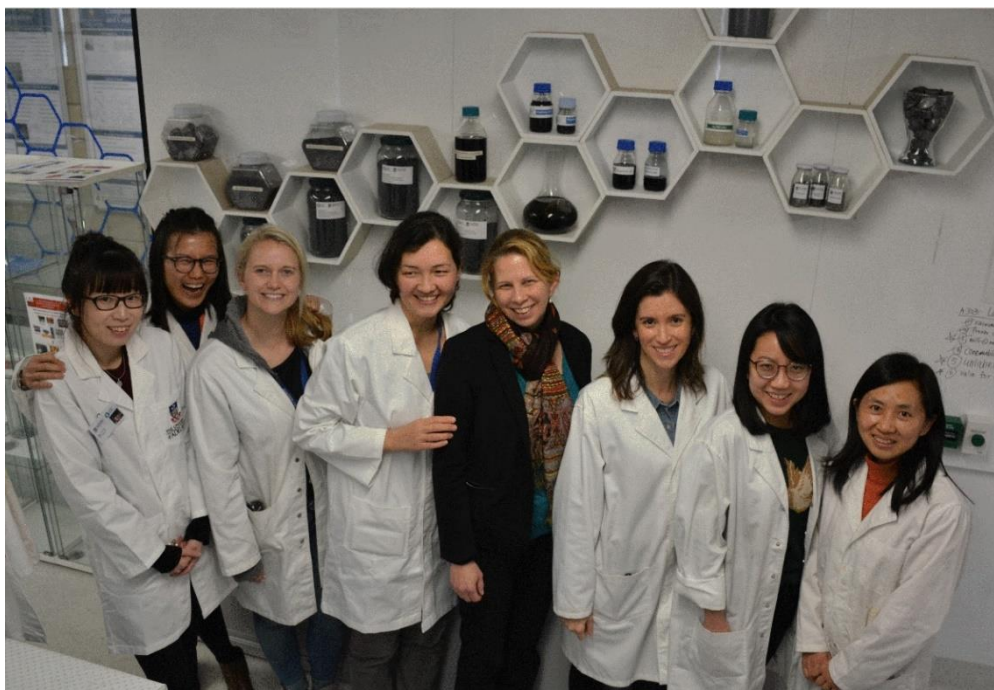
Diversity improves creativity and innovation as well as team performance.

The Hub actively works to promote diversity and is proud to have a team representing 12 countries around the world.

The Hub also strives to improve gender equality in the team and representation in the broader engineering discipline.

This year we took advantage of a new initiative from University of Adelaide initiative to advertise a women-only post doc position. This process enabled evaluation of strong academic candidates without weighting gender differences and relative opportunities.

Hub members now include **25 % women** and we will continue to look for opportunities to improve inclusivity in the team.



Above: The Hub team includes the largest proportion of women in an engineering research group at UoA.

VISITORS AND ENGAGEMENT

The Graphene Hub at UoA as the having respected standing as the leaders in graphene translation field top graphene welcomed over 100 visitors from industry, overseas, government, universities, NGO and schools touring the labs, facilities and continued to showcase our research activities and products development and discuss collaboration

International Visitors and Delegation

Visiting researchers included our collaborators (UK, EU, China, South Korea, India) and delegates from international Universities in China, Vietnam and Malaysia (pictured below) visited the Hub's Lab. **Dr Andrew Pollard**, program leader of nanomaterials at National Physical Laboratory (NPL,UK) spent one week with Hub researchers on a joint standardization and VAMAS project (pictured below and right).



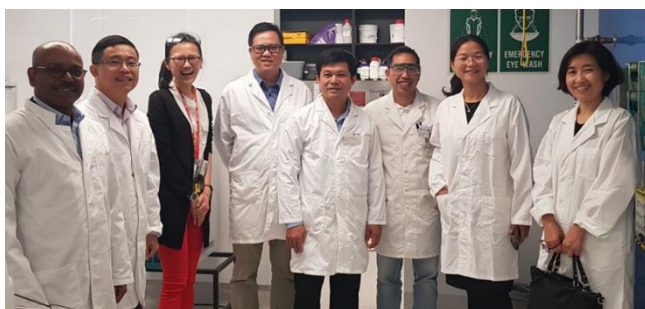
Australian Defence and Space Industry: The Hub was visited by several DST and SA Australian Space representatives to look Hub capabilities and discuss collaboration on radar, EMI, radiation shielding and composite materials.

Government, NGO and other visits: The Hub hosted SA state police delegations to present Hub program and involvement in security projects.



New Industry partners and investors

The Hub was visited by +50 Industry representatives keen to invest in graphene-products or explore the opportunities that graphene-enabled technology may provide to their products. Several potential investors and venture capitalist were hosted to showcase the Hub program and discuss potential investment opportunities.



University and research org. visits: over 100 individual researchers, research teams, PhD and research students from interstate and SA organisations (UNSW, QUT, QU, RMIT, CSIRO, Flinders, UniSA, SARDI, SAMRHI). The Hub also has links with other ARC Hubs. UNSW SMaRT Hub Director **Prof Veena Sahajwala** (below) and her team visited the Hub which resulted to establishing 2 joint collaborative projects.



MEDIA AND OUTREACH

Research outcomes from the Hub were promoted across multiple platforms including traditional and social media

Traditional media

- 5 University media releases resulted in 2 newspaper articles and over 100 web news posts/ articles and blogs.
- Our industry partners promoted our research in over 10 ASX releases that resulted positively on share prices.

- The Hub's You Tube channel was further developed with 14 technology videos accumulating over 1400 views, along with animated graphene explainer videos and new Hub animated logos and branding: <https://www.youtube.com/channel/UC6zcFDOeuVAX2fqbbncWmAQ/featured>

Social media and online engagement

This year the Hub also launched a new website. The new site includes a regularly updated blog and events site:

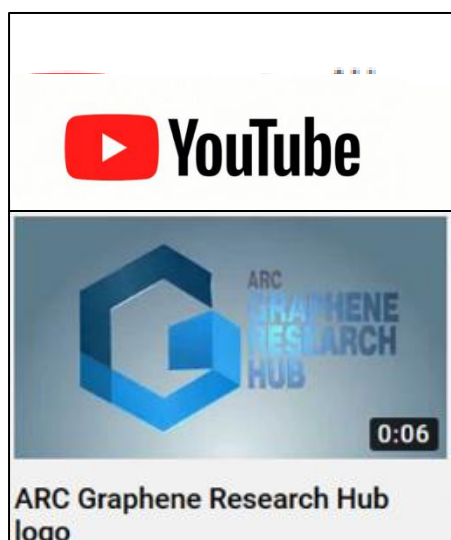
<https://arcgrapheneresearchhub.com.au>.

- Social media presence continued to grow with Facebook and Instagram profiles established. The Hub's Twitter profile now has over 330 followers and over 180 tweets reaching 12K-21K impressions per month.

Outreach

Members of the Hub have been actively promoting the outcomes from the Hub and related research. This has included:

- Over 10 lectures to public, government, and professional organizations including DSTO/space representatives
- Hosting High School students to visit Graphene lab at University of Adelaide
- Presentations and facility tours at the University of Adelaide University Open Day



HUB'S SOCIAL LIFE AND EVENTS

As well as conducting cutting edge research to solve global problems, Hub team members also enjoy an active and vibrant social life with joint group lunches, barbeques, welcome and birthday parties, farewells, fundraising, award celebrations, bowling, social networking, and joining events like the Corporate Cup.



Regular barbeques in the Adelaide Botanic gardens and joined lunches with the UniSA team (CI Ma).



Adelaide Hub Corporate Cup team

Farewell for Hub Int. visiting researchers



PhD award celebration Dr Shervin Kabiri



International food from 10 countries

RESEARCH OUTPUTS 2019

The Hub research outputs include 1 book chapter, 30 journal papers, 1 conference paper over 20 conference abstracts and presentations, and 5 patents applications

Patents

1. Md J Nine, D Losic, Graphene based fire retardants, US patent US20190249084A1, 2019-08-15.
2. Tran, T.S.; Dutta, N.K.; Choudhury, N.R. Water-redispersible dry graphene powder. AU Patent, under review.
3. J Ma, Graphene for polymer processing (submitted)
4. D. Losic, D. Dubal, M. Moussa, Graphene super capacitor (Provisional patent, 2019/35520857)
5. D. Losic, L. Yu, A. Santos et al Radiation shielding materials (patent appl subm.)

Book Chapter

1. TT Tung, KM Tripathi, TY Kim, M Krebsz, T Pasinszki, D Losic. Carbon Nanomaterial Sensors for Cancer and Disease Diagnosis. Carbon Nanomaterials for Bioimaging, Bioanalysis, and Therapy 2019, John Wiley & Sons Ltd

Journal Articles

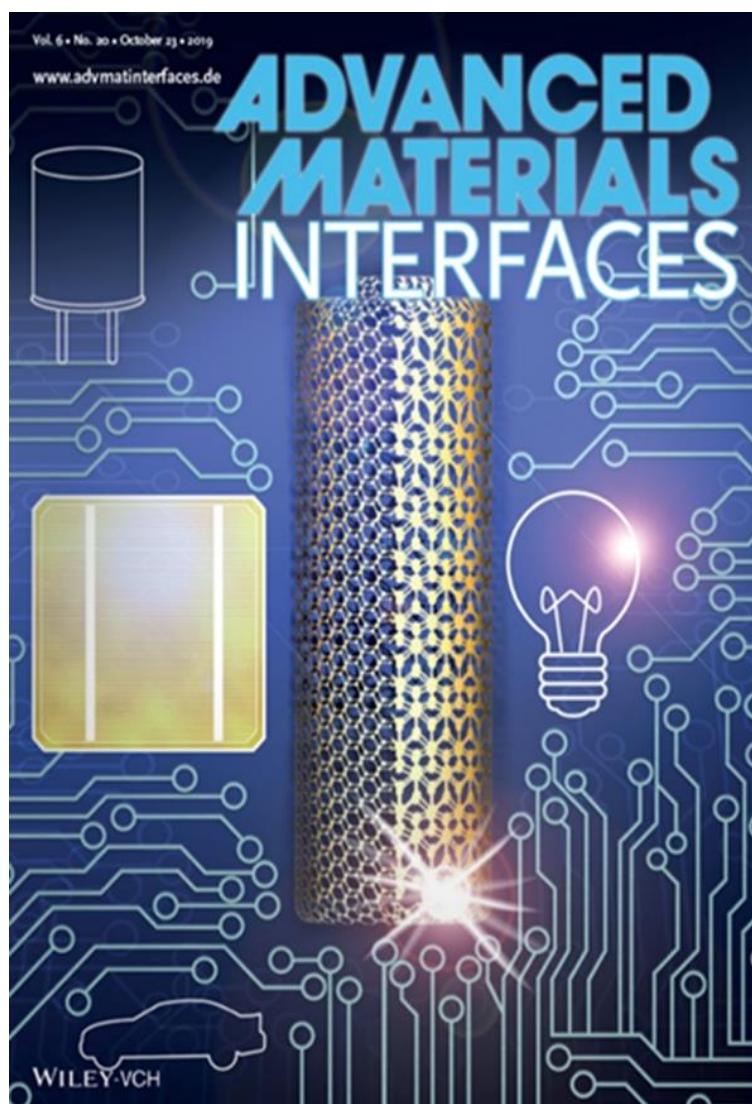
1. M.Shaibani, M.Sharifzadeh, R.Singh, C.D. Easton, M.C.D. Cooray, N.Eshraghi, T.Abendroth, S. Dorfler, H.Althues, S.Kaskel, A.F. Hollenkamp, M.R. Hill, M.Majumder, Expansion Tolerant Architecture for Stable Cycling of Ultra-High Loading Sulfur Cathodes for Stable Cycling of Lithium Sulfur Batteries, **Science Advances**, accepted in 2019, 2020, 6(1), eaay2757
2. H. Wang D. Tran, J. Qian, F. Ding, D. Losic, MoS₂/Graphene Composites as Promising Materials for Energy Storage and Conversion Applications, **Adv. Mater. Interfaces** 2019, 6, 1900915 (journal cover) (work by visiting PhD from China)
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5. Md J. Abedin, T. D Gamot, S. T Martin, M. Ali, K. I. Hassan, M. S. Mirshekarloo, R. F Tabor, M. J Green, M. Majumder, Graphene Oxide Liquid Crystal Domains: Quantification and Role in Tailoring Viscoelastic Behavior, **ACS Nano**, 2019, 13, 88957-8969
6. Z Yang, J Ma, B Bai, A Qiu, D Losic, D Shi, M Chen, Free-standing PEDOT/polyaniline conductive polymer hydrogel for flexible solid-state supercapacitors, **Electrochimica Acta**, 2019, 134769 (CI UniSA and UoA collaborative work)
7. SJ Watts-Williams, TD Nguyen, S Kabiri, D Losic, MJ McLaughlin, Potential of zinc-loaded graphene oxide and arbuscular mycorrhizal fungi to improve the growth and zinc nutrition of *Hordeum vulgare* and *Medicago truncatula*, **Applied Soil Ecology**, 103464
8. M Bariana, JA Kaidonis, D Losic, S Ranjitkar, PJ Anderson, Titania nanotube-based protein delivery system to inhibit cranial bone regeneration in Crouzon model of craniosynostosis, **International Journal of Nanomedicine** 2019, 14, 6313-6324
9. K Li, X Liu, T Zheng, D Jiang, Z Zhou, C Liu, X Zhang, Y Zhang, D Losic, Tuning MnO₂ to FeOOH replicas with bio-template 3D morphology as electrodes for high performance asymmetric supercapacitors, **Chemical Engineering Journal**, 2019, 370, 136-147 (Collaborative work with Chongqing Uni, China)
10. D.A Navarro, M Kah, D Losic, RS Kookana, MJ McLaughlin, Mineralisation and release of ¹⁴C-graphene oxide (GO) in soils, **Chemosphere**, 2019, 124558
11. TT Nguyen, TT Tung, D Losic, LTL Anh, XS Nguyen, Electromigration with enhanced green emission in the titanium dioxide

- nanotube/graphene composite, **Current Applied Physics**, 2019, 19(10), 1082-1087
12. S Ishaq, F Kanwal, S Atiq, M Moussa, D Losic Synthesis of three phase graphene/titania/polydimethylsiloxane nanocomposite films and revealing their dielectric and impedance properties, **Ceramics International**, 2019, 45 (7), 8713-8720
(work by visiting PhD from Pakistan)
 13. S Ishaq, M Moussa, F Kanwal, M Ehsan, M Saleem, TN Van, D Losic Facile synthesis of ternary graphene nanocomposites with doped metal oxide and conductive polymers as electrode materials for high performance supercapacitors, **Scientific reports**, 2019, 9 (1), 5974, 3
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 14. TT Tung, NV Chien, N Van Duy, N Van Hieu, MJ Nine, CJ Coghlan, D. Losic, Magnetic iron oxide nanoparticles decorated graphene for chemoresistive gas sensing: The particle size effects, **Journal of colloid and interface science**, 2019, 539, 315-325
 15. IB Andelkovic, S Kabiri, RC da Silva, E Tavakkoli, JK Kirby, D Losic, M. McLaughlin, Optimisation of phosphate loading on graphene oxide-Fe (iii) composites—possibilities for engineering slow release fertilisers, **New Journal of Chemistry** 2019, 43 (22), 8580-8589
 16. Y Wei, P Yuan, D Liu, D Losic, D Tan, F Chen, H Liu, J Zhou, P Du, Y. Song, Activation of natural halloysite nanotubes by introducing lanthanum oxycarbonate nanoparticles via co-calcination for outstanding phosphate removal, **Chemical communications** 2019, 55 (14), 2110-2113
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- Conference papers**
1. YS Guo, D Tran, D Losic, LM Shor, Pore-Scale Effects of Dilute Organic Macromolecules and Nanoparticles to Inhibit Moisture Loss, 2019 AIChE Annual Meeting
- Conference abstracts and presentations**
1. M Majumder, International Workshop on Advances in 2D materials at the Indian Institute of Science, Education and Research, Thiruvananthapuram, India from July 22-23, 2019.
 2. Jun Ma. Stretchable Strain Sensors Based on Polymer/Nanomaterial Composites, RubberConf 2019, April 17-18, 2019, Hangzhou, China
 3. Jun Ma. Recent Progress of Epoxy/Nanosheet Composites, CAMT2019 – 30-year Progress in Advanced Materials Technology, April 19-21, 2019. Tongji university, Shanghai, China
 4. D. Losic, Md J Nine: Australian Flame Retardants and Fire Safety Workshop (FRFS-2019), 5th August 2019 in Brisbane, Queensland. (invited)
 5. S.Hooshmand Zaferani, R.Ghomashchi, D.Vashaei, Thermoelectric Properties of P-type MnTe/Graphene Nanocomposites, , Advanced Nano and Energy Materials, 4-6 December 2019, The University of Western Australia, Perth, Australia.
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 7. Md J Abedin – poster presentation, Graphene Week 2019, Sept 23-27, Helsinki.
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 10. M Majumder (keynote), Functional role of 2D materials in high performance Li-S batteries, International Workshop on Advances in 2D materials, 22-23 July, 2019. IISER, Thiruvananthapuram, India.
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 12. D Losic Graphene Week – Panel discussion: Future of graphene, Graphene Week 2019, Sept 23-27, Helsinki, Finland (Panellist)
 13. D Losic (convenor and keynote), EU-Australia workshop, Graphene Week 2019, Sept 23-27, Helsinki, Finland
 14. Jun Ma et al: Graphene composites and their applications, EU-Australia workshop, Graphene Week 2019, Sept 23-27, Helsinki, Finland (invited)
 15. S. Hunt, Graphene Solution technology and graphene commercialization, EU-Australia workshop, Graphene Week 2019, Sept 23-27, Helsinki, Finland (invited)
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18. D. Losic et al. Advancement on graphene composites and heterostructures for engineering of new products for environmental and emerging applications, Grapchina, 2019, 21-23 Oct. (plenary lecture)
19. D. Losic, Panel discussion International collaboration and industrialization of graphene research, Grapchina, 2019, 21-23 Oct.
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21. D. Losic et al. Grapchina, Graphene stanadriztions and characterizations: problems and progress, 2019, 21-23 Oct. (keynote lecture)
22. D. Losic et al. Graphene materials and their emerging application, Foreign Experts Symposium on Advanced materials, Linyi University China, 29-30 Oct, 2019 (plenary lecture)



Research published by CI Losic and Dr Diana Tran, was featured on the back cover of Advanced Materials Interfaces in October 2019, entitled "Supercapacitors: MoS₂/Graphene Composites as Promising Materials for Energy Storage and Conversion Applications". Cover design by Ray Hirst.



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