

## Report on Third Australia – EU Workshop on Graphene and Related Materials, 2023

**Date:** 30-31 March 2023

**Location:** Monash University, Melbourne, Australia

### **Chairs:**

- Dr Ken Teo (AIXTRON)
- Prof Dusan Losic (University of Adelaide)
- Prof Mainak Majumder (Monash University)
- Prof Michael Fuhrer (Monash University)

**Summary:** The third Australia-EU Workshop on Graphene and Related Materials was held on 30-31 March 2023 at Monash University in Melbourne, Australia. By bringing together leading researchers from Australia and Europe, this workshop aimed at providing an open forum for discussing cutting-edge research in the field and fostering scientific exchanges, practices and ideas related to the current and emerging topics associated with graphene and 2D materials. A broad spectrum of topics were discussed in significant depth, with talks and discussions addressing topics ranging from application and commercialisation to new fundamental concepts, synthesis, composites, membranes, biomaterials, electronics, sensors, composites, coatings and energy devices.

Approximately 50 attendees were present, including around 10 industrial delegates from Australian graphene companies. The workshop also included tours of the Melbourne Centre for Nanofabrication (MCN), the Advanced Manufacturing with 2D Materials (AM2D) facilities, and the Australian Research Council (ARC) Centre of Excellence in Future Low-Energy Electronics Technologies (FLEET).

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## Day 1: Melbourne, 30 March 2023



*New Horizons Building, Clayton Campus, Monash University*

The workshop took place at the New Horizons Building, Clayton campus of Melbourne’s Monash University. Given the previous Australia-EU Workshop on Graphene and Related Materials was held in 2019 in Helsinki with the gap due to covid restrictions, the participants’ enthusiasm at seeing one another again at this workshop was palpable and a cause for celebration. Prof Jari Kinaret (Graphene Flagship Director) made a comment that captured the spirit of the event well: “It’s always nice to meet old colleagues and make new friends.”

The workshop was opened by Dr Phillip Sheath (Hub Manager at the ARC Research Hub for Advanced Manufacturing with 2D Materials) with an Acknowledgement of Country, which is an Australian cultural practice originating in Aboriginal and Torres Strait Islander cultural protocols of welcoming visitors to Australian soil. An Acknowledgment of Country is often spoken at the beginning of meetings, gatherings, and events held within Australia as a means of showing respect both to visitors and to the traditional custodians of the land – namely, the Indigenous peoples within Australia.

Notably, this value of respect for the land and its inhabitants underpinned a significant amount of the Australian research and industrial work presented at the workshop. Sustainability, environmental conservation, and good management of resources are important issues within Australian society, Australia being a country simultaneously rich in resources and liable to being severely impacted by climate change, such as through fires, floods, droughts, and other extreme weather events. In terms of thematic overlap, these issues were also of major concern to the EU delegates: the Graphene Flagship places a strong emphasis on sustainable graphene applications as well, and encapsulates various projects with strong environment elements, such as research into recycling and repurposing. Consequently, delegates found that their work was often complementary both in research themes and values.

The three key themes covered in Day 1 of the workshop were:

- Opportunities, Fundamentals and Composites;
- Energy Storage; and
- Sustainability and Safety.

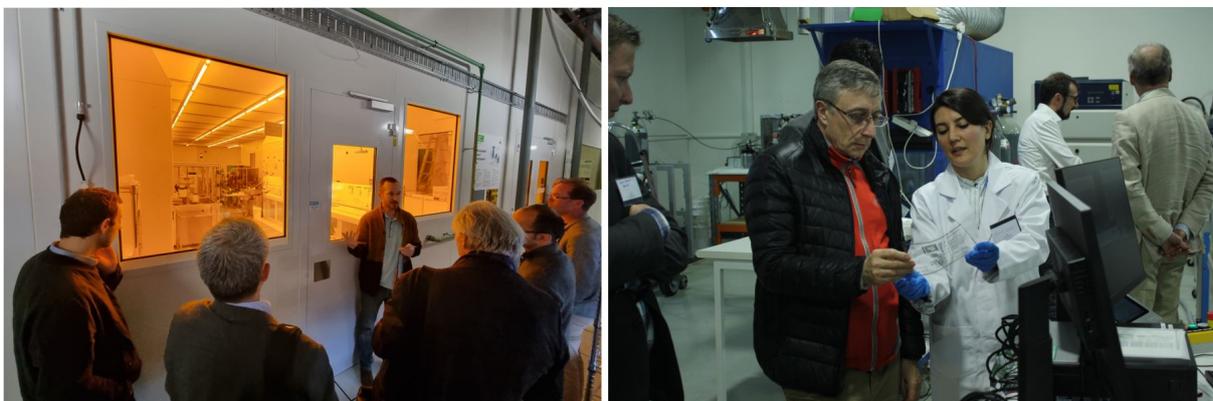
Prof Kinaret's opening talk gave context to the workshop providing an overview of the Graphene Flagship's evolution and achievements over the last 10 years, which offered insights into how disruptive graphene technologies can move from academic laboratories into applications for society. Prof Dusan Losic then covered industrial production of graphene (100T/year) and tuning its properties for innovative use in anti-corrosion, fire protection, sound and radiation shielding, sensors, environmental remediation and nutrient delivery in agriculture.

This was followed by presentations covering the electronic properties of bilayers of twisted 2D materials; gallium oxide passivated graphene devices; graphene-reinforced elastomers; graphene-based batteries and supercapacitors; graphene ion nanochannel; plasma and microwave conversion of methane and agricultural waste into graphene; and toxicity of graphene-based materials. More information in the Program Book for the workshop. These topics lean towards transitioning to cleaner energy, supporting efforts to mitigate climate change, and reducing impact on Australia's natural resources.

Thought-provoking questions that emerged from the workshop's first day included:

- Can we turn any organic waste into graphene-like carbons for different applications as a means of recycling?
- How can supercapacitors be incorporated into urban infrastructure? (such as, for instance, on the roofs of trams)
- Australia is a fortunate country, having been blessed with an abundance of natural resources including minerals required for the energy transition – so how can researchers and industry contribute to this energy transition most effectively?
- What can Australian collaborators learn from the challenges and achievements of the Graphene Flagship project and its specific structure and goals?

After the talks, half the attendees toured the Melbourne Centre for Nanofabrication (MCN) and the other half visited two Monash-based labs: the Advanced Manufacturing with 2D Materials (AM2D) lab, and the ARC Centre of Excellence in Future Low-Energy Electronics Technologies (FLEET). These visits were excellent opportunities for participants to learn more about projects underway, technical capabilities, equipment and facilities, and also to meet with researchers – including students – who discussed their research and showed participants their experiments and results.



*L-R: The Melbourne Centre for Nanofabrication; the Advanced Manufacturing with 2D Materials lab.*

In the evening, the speakers and the sponsors of the workshop came together for a dinner hosted at the Campus Centre of Monash University. This proved both to be a wonderful opportunity to enjoy

more warm Australian hospitality, as well as to interact further with fellow researchers and industry leaders and to share ideas in an informal setting.



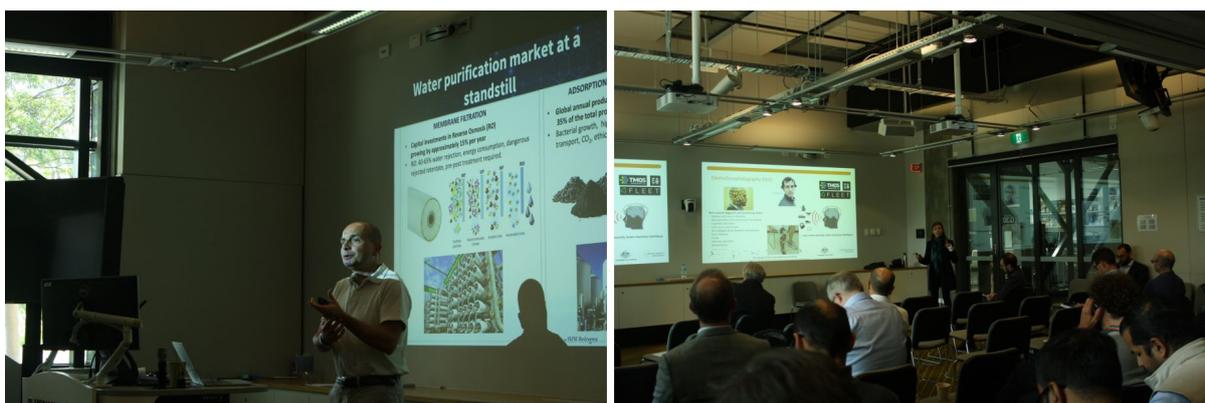
*Dinner at the Campus Centre, Monash University*

## **Day 2: Melbourne, 31 March 2023**

The second day of the workshop was composed of more presentations as well as a forum and panel discussion. The key themes covered were:

- 2D applications: photonics, optoelectronics and electronics;
- Wearables and water purification; and
- Standardisation and commercialisation.

Projects related to electronics and wearable technologies have been among the Graphene Flagship's most successful, which meant these themes were especially relevant to EU delegates keen to share their knowledge as well as learn from Australian researchers working in similar areas.



*Presentations on Day 2 of the workshop. L-R: Vincenzo Palermo speaking; Francesca Iacopi speaking.*

Optical devices (graphene saturable absorbers, graphene optical modulators, hBN single photon emitters), heat pipes, wafer scale/roll to roll growth, integration of graphene for device manufacturing, wearables and biomedical applications were a strong theme running through the second day. Presentation topics also included biocompatible graphene sensors that can detect and monitor diseases and brain-computer interfaces based on graphene electrodes. The technical

presentations concluded with graphene membranes and their application in water purification, using graphene to increase the green-footprint of concrete, quality and standardisation issues for industrialising the use of graphene. Further details are again available in the Program Book for the workshop.

The panel discussion in the afternoon focused on some of the hard practicalities related to scaling up graphene – which has long figured as a challenge to graphene commercialisation. Following several key talks related to this topic, both from Graphene Flagship representatives and industry, a panel of delegates from both Australia and the EU discussed graphene commercialisation challenges at length and invited audience members to participate in the discussion as well. Key points covered included quality control and standardisation, as well as collaboration. A salient point that emerged was that quality control and standardisation are sometimes seen as greater barriers to commercialisation than they actually are, and that technologies already exist that can help ensure a high degree of standardisation without compromising on quality. Nevertheless, panel discussion members also highlighted that the standardisation process is of great importance for companies seeking to be competitive, and consequently needs to remain a focus area. This is especially true if graphene and related materials are to be competitive not only in the wider market, but also in comparison with other materials and technologies beyond the 2D materials focused on as part of the work of the Graphene Flagship and Australian counterparts. The workshop then ended that afternoon, allowing participants attending from beyond Melbourne to travel to the airport in good time.



*The panel discussion. L-R: Lefthand image: Johan Ek Weis (Chalmers University of Technology), Phil Aitchison (Ionic), Dusan Losic (University of Adelaide, GEIT); Righthand image: Philip Sheath (Monash University), Johan Ek Weis (Chalmers University of Technology), Phil Aitchison (Ionic), Dusan Losic (University of Adelaide, GEIT), Mainak Majumder (Monash University, AM2D), Ashok Nanjundan (Graphene Manufacturing Group).*

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### **Post-workshop feedback and comments**

Feedback regarding the workshop was extremely positive.

Professor Jari Kinaret, Director of the Graphene Flagship, was quick to highlight the calibre of the research shared by Australian delegates at the workshop.

“The workshop was an excellent opportunity to learn of the latest developments in the research and industrial work on graphene and 2D materials being done in Australia,” said Professor Kinaret.

“Graphene applications in the energy sector formed a core theme for several of the researchers, which was encouraging to observe given the present global need for further innovation in the sustainability field.

“Yet the research presented was also far more wide-ranging than energy applications alone. Among other topics, our European delegation was introduced to cutting-edge work in research focus areas including manufacturing innovation, wafer-scale deposition, semiconductors, brain-machine interfaces, and quantum dots for wearable sensor devices.”

The two workshop Chairs based at Monash University also spoke with enthusiasm about the event’s potential to catalyse new collaboration and innovation.

“This workshop between the European Union and Australia was a really excellent exercise,” said Professor Mainak Majumder, Director of AM2D Hub at Monash University.

“In Australia, given the country’s geographical location, it can sometimes be hard to access all the information we need. But over the course of the workshop, we were able to hear from many leaders in graphene and 2D materials research, as well as hear about what is happening in the start-up space. We had the chance to discuss challenges related to graphene characterisation and applications, as well as the opportunities present at the intersections between academia and industry.”

Professor Michael Fuhrer, Director of the ARC Centre of Excellence in Future Low-Energy Electronics Technologies (FLEET) at Monash University, commented on the potential synergies between European and Australian research.

“The work we are doing here at Monash is very complementary to the work being done by the Graphene Flagship,” said Professor Michael Fuhrer.

“The Graphene Flagship is a fantastic effort in that it has really pushed the science and the technology of 2D materials forward. Similar to the Graphene Flagship, we are looking to expand our focus from fundamental research out into applications and products as well. So learning more about what the Graphene Flagship has managed to achieve, and how, is extremely useful for us.”

The Graphene Flagship would like to again extend its thanks to Monash University for hosting the workshop, as well as to the ARC Research Hub for Advanced Manufacturing with 2D Materials (AM2D) and the ARC Research Hub for Graphene Enabled Industry Transformation (GEIT) for co-organising it. We would also like to thank our sponsors: this workshop was made possible thanks to you, and we are grateful for your interest and faith in the value of our work.

Indeed, graphene research and industry are clearly growing in both hemispheres – and future collaboration between Europe and Australia on graphene and 2D materials holds great promise. Connections and exchanges such as the ones that took place at this workshop form the bedrock of this collaboration. With such foundations established, it will be exciting to see how Europe and Australia will bolster each other’s efforts in the graphene space in years to come; and, given the strengths of both regions, there are many reasons to be optimistic.

**Key websites for further information:**

<https://graphene-flagship.eu/>

<https://am2d.org/>

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

<https://www.fleet.org.au/>