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GRAPHENE

MAGAZINE 2019



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Table of Contents

Contents

From the Editor	3
Profile: Luciana Löberg	4
The Graphene Flagship Means Business	6
The Future Is Graphene, The Future Is You	10
Graphene Flagship at the Lindau Nobel Laureate Meeting	13
Graphene Goes to Space	14
Car of the Future	16
Graphene Flagship Product Gallery	26
Bringing Graphene and New Materials to Market	28
Unlocking Thousands of New Materials.....	31
Profile: Mar García-Hernandez	32
Wearable Technology Seeks New Materials to Enhance Functionalities	34
Women in Graphene.....	36
The Graphene Flagship's Validation Service	38
Phyphox – Physical Phone Experiments	40

Programme

Chair's Welcome	20
Tervetuloa! (Welcome!)	21
Programme Overview.....	22
Conference Map	24
Exhibitors & Sponsors	25



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Partnering mechanisms increase the reach of the project

21 COUNTRIES

Europe-wide collaborations improve results

6 SPEARHEADS

Targeted research yields technology ready prototypes

9 SPINOFF COMPANIES

Graphene is hitting the market with innovative products



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From the Editor

Graphene Week is always an exciting opportunity to learn about the latest advancements in graphene and related materials research and innovation, but this year the event promises to be even more spectacular. Not only will we offer more workshops, fringe sessions and opportunities to collaborate with critical European agencies and projects, but the event is also a part of the Finnish Presidency.



As an official side event of Finland's Presidency of the Council of the European Union, Graphene Week will enjoy increased prominence, making our work more visible to the European public, the media and decision makers.

Let's take this opportunity to elevate the conversation about graphene and related materials in Europe and globally.

This conference is built on the efforts of a great number of people. In this issue you will get to know Event Manager Luciana Löberg and understand her inspiration for Graphene Week, our Conference Chair Sanna Arpiainen, and our host partner VTT. You will also get to know many other Graphene Flagship members that will present their work this week.

Don't stop here. Graphene Week is an excellent opportunity to meet these people and many other excellent researchers and innovators in the graphene space. Our new Business Networking Lounge will create a dedicated area for discussions about new collaborations. Lunches, coffee breaks and the poster sessions also present excellent networking opportunities. Don't forget to keep the conversations alive after Graphene Week on our social media channels!

Rebecca Waters

Communications Officer
Graphene Flagship



GRAPHENE FLAGSHIP DISSEMINATION TEAM

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Profile: Luciana Löberg

By Rebecca Waters

Anyone who has participated in Graphene Week in the past five years will know Graphene Flagship Event Manager Luciana Löberg, who has skillfully navigated this growing conference across Europe since the inception of the project. Here she gives us her insights on the history of Graphene Week and what makes it such a unique conference.

Graphene Flagship: What can you tell us about Graphene Week's history?

Luciana Löberg: The Graphene Flagship has been putting on Graphene Week since the project launched, but it was already an established scientific conference when we took it over in 2014. The Graphene Flagship took on the conference, now in its fourteenth year, to benefit its partners and associated members as a platform for them to share their research results and to network with their peers.

Now, as the field of graphene has grown and evolved, the conference has also evolved. Graphene Week's expanding scope is an indicator of the growth in the field of graphene and related materials. We have moved from pure fundamentals to applications and innovation.

Graphene's growth has triggered an interest from various fields: biomedical and space exploration, among others. This has led to the creation of ties between Graphene Week and other organisations and European projects working in related fields. This year we are collaborating with a number of organisations including the European

Space Agency, COST, EuroHPC (European high-performance computing) and the European Patent Office.

GF: What makes Graphene Week unique?

LL: Graphene Week is the only graphene conference that has a large focus on fundamental science in addition to the applications, a balance other conferences don't have, making it unique in the landscape of graphene events.

The conference structure, with layers of content including oral presentations, fringe sessions, workshops, poster sessions and other joint events makes the conference special. Furthermore, the establishment of the Scientific Advisory Board and the Programme Committee puts the content of the conference in the hands of experts in graphene and related materials. Because Graphene Week is a non-profit event, these experts are free to highlight the latest ground-breaking research and innovation without commercial considerations. For this reason, every edition of Graphene Week is unique and takes on its own character.

GF: What is your personal favourite thing about Graphene Week?

LL: Graphene Week is such a fantastic opportunity to work with so many stakeholders around Europe. It's rewarding to collaborate with so many fantastic people to deliver an excellent delegate experience.



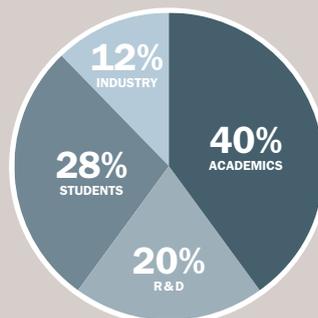
Graphene Flagship Event Manager Luciana Löberg

GRAPHENE WEEK BY THE NUMBERS



90%

VISITOR SATISFACTION



VISITOR PROFILE



50

COUNTRIES REPRESENTED

GRAPHENE WEEK SPREADS KNOWLEDGE THROUGHOUT EUROPE



The Graphene Flagship Means Business

By Carla Mateus

Leiden University spin-off, Crucell, is a world-famous biotechnology company. Johnson & Johnson acquired the business for close to \$2.4 billion back in 2011. This mammoth sum of money highlights the potential of university or corporate spin-offs and their investment attraction.

There is a growing appetite for spin-offs and SMEs that have grown out of research. Here are four SMEs that are setting the pace in graphene and related materials (GRM) commercialisation that will be present at Graphene Week 2019.

EMBERION

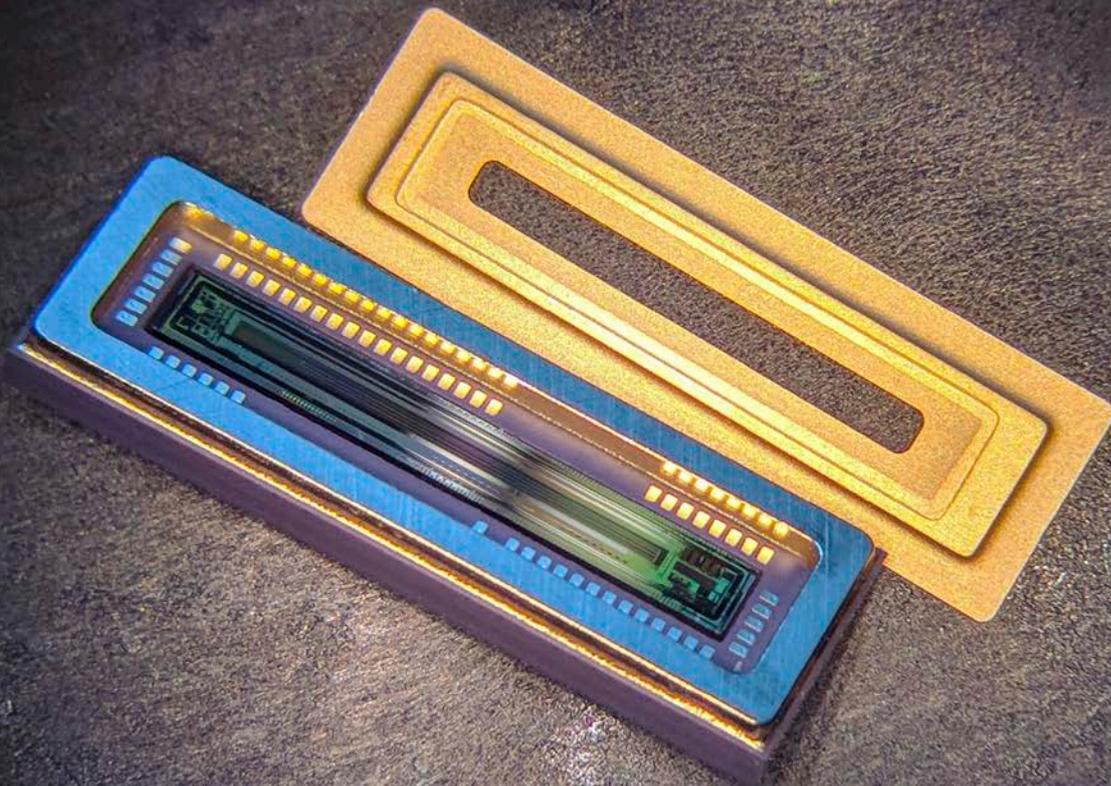
Emberion develops and produces graphene photonics and electronics that revolutionise infrared photodetectors and thermal sensors. Applications include hyperspectral and thermal imaging, night vision and X-ray detection.

The business was a spin off company from Nokia. Following a long history of graphene research inside Nokia's research organisation, the team joined the Graphene Flagship to take the work carried out on optoelectronics to the commercial market.

"Emberion was established in quite an early phase of product development," explained Tapani Ryhänen, CEO of Emberion. "We had promising results and functional prototypes from our research and above all, we were able to get an agreement with venture capital investors.

“ Emberion is focusing on various spectrometer and machine vision applications by producing novel image sensors. We provide products with broad wavelength range and low noise. Our image sensors can be used for example in agriculture, food processing and pharma industries. ”

During the next year, Emberion will start delivering its first imager products. The business will also commence with the Graphene Flagship GBIRCAM spearhead project, together with its partners, to bolster the readiness of graphene-enabled optoelectronics in industry.



Emberion's new hyperspectral graphene photodetector can enable on-site analysis of food and agriculture products using infrared detection — at a lower cost than existing indium gallium arsenide infrared sensors.

GRAPHENE

World leading graphene producer Graphenea, founded in 2010, was one of the first industrial partners to join the Graphene Flagship program. Graphenea participated in the proposal stages of the Graphene Flagship, collaborating closely since the inception of the EU-funded program.

Business is booming for Graphenea. In 2018, the business generated €1.6 million, and is on track to grow by 25% in 2019.

Graphenea's facilities are located in San Sebastián, Spain and Boston, USA. The 25 employees at Graphenea contribute to the successful development of graphene applications, including supplying CVD Graphene films, Graphene Field-Effect-Transistors chips (GFETs), Graphene Foundry Services (GFAB) and Graphene Oxides. Graphenea's operation spans across more than 60 countries and a wide range of sectors.

"The collaboration between Graphenea and the Graphene Flagship has evolved over the last six years," explained Iñigo Charola, business development director at Graphenea. "Our work has become incredibly industry-orientated, with focused spearhead projects to bring applications to market quickly and effectively."

"Today, we are focusing not only on the production of graphene, but also developing our processing capabilities of the material. Our partnership with the Graphene Flagship provides the support to help reach this goal."

BEDIMENSIONAL

BeDimensional produces and develops graphene and 2D crystals for the manufacturing and energy industries. Its main target applications relate to coatings and paints and material production for energy applications.

As a start-up, BeDimensional was created as a spin-off company of the Istituto Italiano di Tecnologia (IIT).

The research group started out their research in fundamental studies of electronic properties of two-dimensional semiconductor systems. They were also investigating some possibilities to tune the interaction of hydrogen and carbon by curving a graphene sheet. For this latter study, the team were approached in the initial stages of the Graphene Flagship project to set-up a work package on hydrogen storage.

After a two-year incubation period within the institute itself, BeDimensional moved onto the market after the acquisition of 51% of its shares by the Camponovo. The definitive push towards the path of industrialisation came at the end of 2018, after the €18 million investment from Pellan Group.

So, what's next for BeDimensional?

After closing this round of investment, BeDimensional is now fully immersed in implementing its industrial and commercial strategies. The first production line of two-dimensional crystals is already operational and the business is in the process of setting up more laboratories for research and development.

"We need to strategically position ourselves at the right level of the industrial value chains linked to each specific application," explained Vittorio Pellegrini, founder and scientific advisor for BeDimensional. "We believe it is crucial to establish partnerships and joint ventures with appropriate global players. At the same time, we will reinforce our investment in R&D by attracting the best people on board."

BeDimensional has a clear mission and knows how it's going to reach its business goals. Watch this space.



Graphenea produces graphene for customers in over 60 countries in its facilities in Spain and the USA.



BeDimensional's first production line of two-dimensional crystals is already operational with additional laboratories on the way.

VERSARIEN

Versarien, headquartered in Cheltenham, UK, is an engineering solutions company that delivers novel technologies for industrial applications. Through subsidiary companies, Versarien delivers targeted solutions as well as research and development into new, complementary technologies.

Versarien was founded in 2010 and has been an associate member of the Graphene Flagship since 2018, collaborating closely with researchers in the project.

The company has acquired multiple businesses under the Versarien group, including two spin-offs from high-profile universities carrying out graphene research.

In 2014, 2-DTech joined the group. 2-DTech was originally formed by the University of Manchester to manufacture and supply high quality graphene for research and development. It has now grown into a commercial operation not only supplying high grade graphene and other 2-D materials, but also working on the application of graphene in product development projects.

In 2017, Versarien acquired Cambridge Graphene Ltd. from the University of Cambridge. Cambridge Graphene develops inks, composites and supercapacitors based on graphene and related materials, using processes developed at the Cambridge Graphene Centre.

The Cambridge Graphene Centre's mission is to investigate the science and technology of graphene and other carbon allotropes, layered crystals and hybrid nanomaterials. The spin-out company has commercialised graphene inks for novel technology applications.

These two Graphene Flagship spin-offs join the numerous other companies in the Versarien group, creating a real force to be reckoned with for graphene commercialisation and business growth.

Graphene Week 2019 is your opportunity to hear more about these businesses, to learn from the leaders who are setting the pace in the graphene market. With big players, such as Crucell, showing exactly what is possible of spin-offs and SMEs, the businesses that have spawned out of graphene research will no doubt play a huge role in bringing graphene products to the mass-market.



Versarien's headphones containing the graphene coating Nanene enhance both the high-end (treble) and the low-end (bass) of the audio frequency wave.

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The Future Is Graphene, The Future Is You

By Laura England

Where will you be in 2030? *The Graphene Technology and Innovation Roadmap* predicts that graphene-enabled on-chip optical data, spin-logic devices and mind-blowing 6G networks will all be in development — and who knows what other innovations could emerge by then. That said, none of this will be possible without the minds and efforts of those at the forefront of graphene research, including our network of early career researchers.

The Graphene Flagship has long been committed to investing in young, talented scientists to assist in the research and development of graphene and related materials (GRMs). Last year, through its school for early career researchers, Graphene Study, the Graphene Flagship held two exclusive events. Titled *2D Materials for Environment and Energy Applications*, the summer edition explored experimenters' techniques in studying energy and environmental applications for graphene, mainly filtration and energy storage technologies.

The winter edition, titled *Structural Characterisation of Graphene-Based Materials*, provided delegates with a strategic overview of the most common techniques and methodologies available to determine the nature, composition and behaviour of graphene and other layered materials. These events allow early career researchers to network with more experienced ones and to form relationships that could help them further their research and careers.

At Graphene Week 2019 in Helsinki, we are hosting more exclusive sessions designed for early career researchers. Are you attending? We spoke to three young researchers about their time working in collaboration with the Graphene Flagship and what they are most excited about at Graphene Week 2019.

Bonnie Tsim, National Graphene Institute at the University of Manchester

Having been introduced to the Graphene Flagship by her supervisor, Professor Vladimir Falko, who leads the Enabling Materials Work Package, Bonnie's area of research looks at the electronic properties of twisted graphene heterostructures, i.e layered materials. Bonnie's research is from a theory point of view, working alongside experimentalists at Manchester.

Have you attended Graphene Week before?

This is my first year at Graphene Week, but I have been to other events organised by the Graphene Flagship. Graphene Study in Obergurgl, Austria, earlier this year, was a fun and academically intense study week — and there were plenty of opportunities to learn about the state-of-the-art research in the field.

I also attended the Women in Graphene 2019 workshop in Manchester, UK, which included a career development workshop that I thought was particularly insightful. I thoroughly enjoyed both events and I'm excited to see what Graphene Week in Helsinki will bring.

There are several sessions planned for early career researchers at Graphene Week 2019, how do you think these can be useful for your career?

The funding session will be particularly helpful, as there are often extra funding opportunities that are not widely publicised. I am also particularly interested in the session to "Master Your Elevator Pitch", which will be run by BBC moderator Jane Powell. I think that eloquently describing your research to different audiences is an important transferrable skill, so I am looking forward to learning more about it.



Bonnie Tsim

What other “alternative” sessions would you like to see in future editions?

I would like to see a business-related challenge. For instance, students, early-career researchers, well-established academics and industry experts working together to pitch an idea or solve a hypothetical business question. I think this would encourage attendees across all stages of their career to interact.

What’s the most exciting potential application of graphene and related materials you’ve witnessed?

Graphene theranostics is a particularly exciting application. Theranostics combines targeted therapy with targeted diagnostics simultaneously and has the potential to greatly improve diagnostics and drug delivery for cancer treatments.

Where do you see yourself in five years?

I was awarded a JSPS Summer Fellowship to do collaborative research in Japan this summer, and I see myself either continuing research at an overseas institution with post-doctoral position or fellowship, or maybe working for a company that has plenty of opportunities to work abroad.

Jakob Ewald Muench, Cambridge Graphene Centre at the University of Cambridge

Jakob’s area of research helps to build components for integrated photonics, primarily for use in datacom and telecom systems. Working from the well-established Cambridge Graphene Centre, he’s been involved in several activities and work projects with the Graphene Flagship.

What was your most valuable experience from Graphene Week 2018?

The Graphene Flagship connects so many different partner institutions and companies — and meeting these contacts

in person was an enriching experience. In fact, at Graphene Week 2018 in San Sebastián, Spain, I met a fellow PhD student, Simone Schuler, studying in Vienna. Since then, she graduated – she is now Dr. Schuler – and we started a collaboration that led to her spending six months in Cambridge to work on an exciting project on photodetectors.

Research into GRMs is incredibly broad, and Graphene Week provides a space to witness innovations from all over the world. Europe, for instance, is a stronghold for applications and it’s great to demonstrate these state-of-the-art applications to the rest of the GRM community.

Do you plan to attend Graphene Week 2019 in Helsinki?

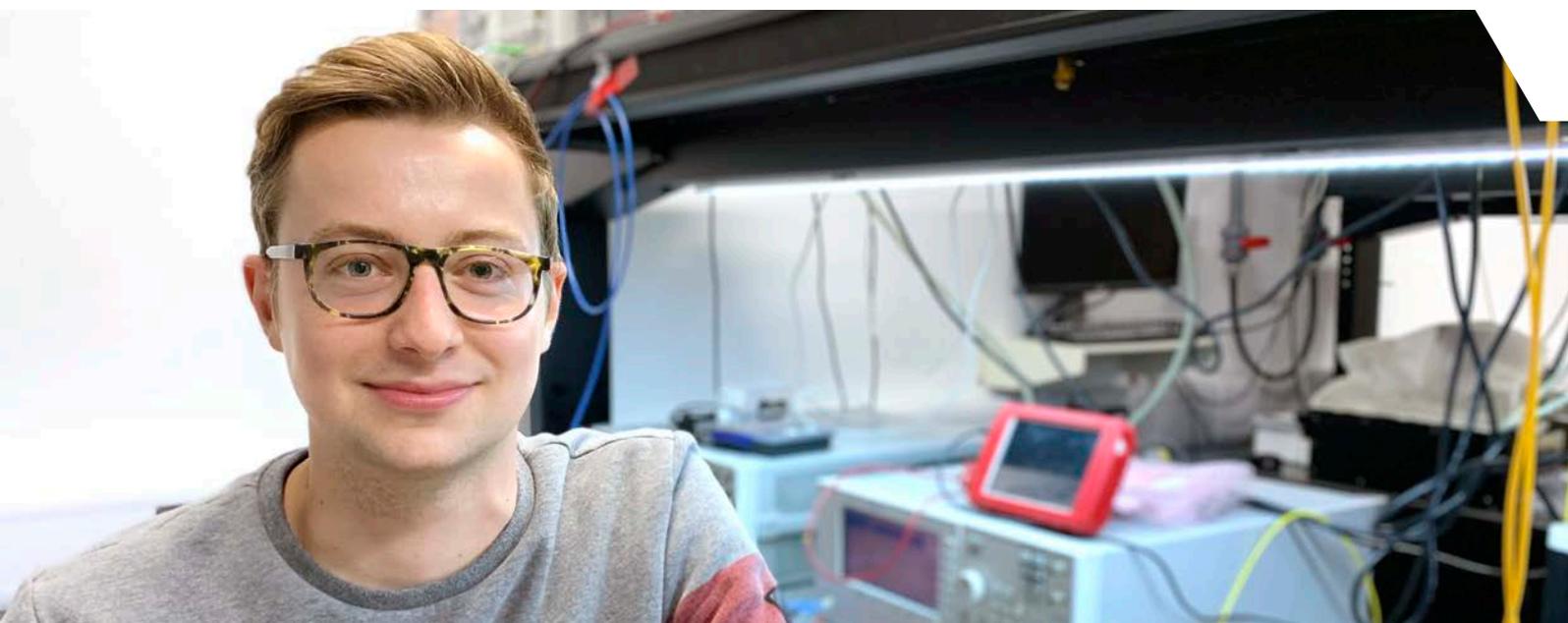
Yes, in fact, I will be giving a talk to present the results from my collaboration with Simone, entitled *Cavity Enhanced Graphene Photodetector*. I’m also interested in sessions on optical electronics, photonics and of course, the Graphene Innovation Forum. There are interesting sessions every day.

What’s the most exciting potential application of graphene and related materials you’ve witnessed?

Naturally, I’m most excited about the projects that I’m working on which are graphene-based transceivers.

Where do you see yourself in five years?

The Graphene Flagship has allowed me to work with people that are brilliant at what they do. Looking to the future, I’m not sure whether I will focus on academic or industrial research, but I’d like to continue to be challenged on a daily basis.



Jakob Ewald Muench

David Mendoza, Instituto de Ciencia de Materiales de Madrid (ICMM), part of the Spanish Scientific Research Council – CSIC

Working from an institute closely associated with the Graphene Flagship, David's area of research focuses on the growth of graphene multilayer structures by physical vapour deposition (PVD) methods by using vacuum growth techniques.



David Mendoza

Have you attended Graphene Week before?

Yes, I attended Graphene Week 2018 in San Sebastián, Spain. It was my first international conference and I learned a lot and came back to my laboratory with a really long list of new experiments I wanted to try out! Normally, you wouldn't have time to read about every area of your investigation, in my case, graphene. However, at Graphene Week, you can gain a huge overview of the state of research on graphene and related layered materials.

Are you attending Graphene Week 2019? If so, what sessions are you looking forward to the most?

I'm definitely attending Graphene Week 2019 in Helsinki! Out of all the sessions, I'm looking forward to the workshop on scientific writing. In this field, the world needs to know what you do, otherwise, it's as if you've never done it.

What's the most exciting area of graphene research you have come across?

It's impossible to choose just one. Superconducting twisted bilayer graphene is really impressive, but it's still too soon to know whether it will have real applications. Other exciting inventions include researchers who are using a single graphene layer to filter salt from seawater, making it suitable for agricultural use. Scientists are also creating flexible electronic devices and more environmentally-friendly and faster batteries — there are so many interesting fields of research, I simply can't decide.

Where do you see yourself in five years?

Probably somewhere out of academia, but still in a science-related field. For instance, there is an emerging industry in graphene and related materials (GRMs) and I hope I'll find my place there when I finish my PhD.

WHAT'S ON AT GRAPHENE WEEK 2019?

Graphene Week's 2019 program for early career researchers begins with a session on career development titled *Master Your Elevator Pitch – Promote Your Research*. The interactive session, held on Tuesday, 24 September at 14:30, will provide young scientists with the confidence to express their own ideas. BBC moderator, Jane Powell, will host the session, teaching researchers how they can elegantly express their ideas for business and industry.

Graphene Week 2019 will also host the Editor of Nature Nanotechnology, Fabio Pulizzi, who will deliver a session on increasing publications of scientific research papers. As every young scientist knows, to get published is to get recognised. This session, held on Thursday, 26 September at 14:30, will provide them with the knowledge to achieve their publishing goals.

That being said, there are a huge host of workshops and sessions at Graphene Week 2019 to grab the attention of early career researchers, including the highly anticipated Graphene Innovation Forum. Held on Monday 23, Tuesday 24 and Wednesday 25 September from 15:30, the Graphene Innovation Forum will demonstrate the most exciting developments in graphene research for wearables, 5G and energy-related technologies.

Check out page 22 for a full schedule of what's on at Graphene Week 2019.

Graphene Flagship at the Lindau Nobel Laureate Meeting

By: Rebecca Waters

Once every year, 30-40 Nobel Laureates convene in Lindau, Germany, to meet the next generation of leading scientists: 600 undergraduates, PhD students, and post-doc researchers from all over the world. The Lindau Nobel Laureate Meetings foster the exchange among scientists of different generations, cultures, and disciplines.

This year the three early career researchers were selected to represent the Graphene Flagship at the meeting after winning the poster prize at Graphene Study. All found it to be an inspirational experience.

Rebekka Garreis, ETH Zurich, Switzerland

What was the highlight of the Nobel Laureate Meeting?

The thing with that meeting is that one highlight leads to the next. If I had to pick one I would say Tawakkol Karman's speech on the last day. She is an incredible, strong woman who knows what she wants and dreams of and would do anything to get there. I also enjoyed talking to the spouses of the laureates and therefore getting some behind the scenes insights.

What was it like to interact with the Nobel Laureates?

It is super interesting to meet so many Nobel Laureates at once, but also a bit overwhelming. Talking to them shows you that they are smart but normal people like you and me who worked hard, followed their passion and had a little bit of luck. For me Wolfgang Ketterle and Donna Strickland were the most inspiring. But also Klaus von Klitzing and Bill Phillips had a stumbling and infectious energy.

Benedikt Frohn, RWTH Aachen University, Germany

What were the highlights of the meeting?

The opening speech of Brian Schmidt managed to directly get me excited for the upcoming days. Among other things, he talked about the challenges society faces with climate change and how science can help with those. He pled in a thrilling way for more openness in science and reminded us of the responsibility we (as scientists) have. On the last day during the panel discussion, he picked up on this and pointed out that for some people we might be the only scientists they know. This gave me a completely new perspective and I will try to remember this from now on.

I could go on but what really made this conference so great were all the little insights, small interactions with other students and Nobel Laureates and the passion for science which seemed omnipresent.

What was it like to interact with the Nobel Laureates?

The interactions with the Nobel Laureates were of different kinds but it was hard not to gain anything from them. In their talks, they often gave private insights on their way to the Nobel prize while also being great at breaking down their different research subjects. I was delighted to find how passionate and excited they are about science, especially Klaus von Klitzing and Bill Phillips. Their endless

curiosity might be what I take the most inspiration from. Moreover, Brian Schmidt with his focus on political responsibility was very motivational.

Would you recommend this event for other young graphene researchers?

Absolutely, not only is it a great way to inspire and motivate the students for their upcoming research while also opening up their perspective and sparking new ideas or allowing idea transfer from other fields, but it also does a great job of promoting the field to other highly qualified students. This is not only done by the talks but also by the students.

Piotr Kapuściński, CNRS, France

What was your overall impression of the Nobel Laureates Meeting?

First of all, I'd like to say that participating in the Lindau Nobel Laureates Meeting was one of the best things to have happened to me in my life, and that I am extremely grateful to Graphene Flagship for letting me go there.

It's hard to pinpoint specific highlights, as the whole meeting was amazing. The boat trip to Mainau Island was definitely something I'll remember. This was the last opportunity to talk to the Nobel Laureates participating in it, so we were less shy and more eager to do so in a bit less formal way.

What was it like meeting the Nobel Laureates?

The Nobel Laureates are certainly heroes for many of the participants of the meeting, therefore the opportunity to interact with them, ask questions and learn about their stories was certainly an exceptional experience. On the other hand, we could also just talk with them over dinner about anything or (in some cases) even dance with them and this made us feel that, besides being the wisest people in the world, they are not much different from us. Also, it was interesting to learn how different their paths to winning the Nobel Prize were and how different their reactions and their "lives after" winning were.



From left to right: Benedikt Frohn, Rebekka Garreis and Piotr Kapuściński

Graphene Goes to Space

By Laura England

Graphene has proven to have some promising applications in space. On 24 June, Graphene Flagship partners, Université Libre de Bruxelles, University of Pisa and the University of Cambridge, in collaboration with the European Space Agency (ESA) and the Swedish Space Corporation (SSC), launched a rocket into space from Esrange, Sweden to further study some of these applications. The experiment aimed to test the possibilities of printing graphene inks in space. Studying the different self-assembly modes of graphene into functional patterns in zero-gravity will enable the fabrication of graphene electronic devices during long-term space missions, as well as help understand fundamental properties of graphene printing on Earth. This mission was also a first step towards the investigation of graphene for radiation shielding purposes, an essential requirement of manned space exploration.

The Materials Science Experiment Rocket (MASER) 14 was launched from the European Space Centre in Esrange, Sweden, thanks to a collaboration between the ESA, SSC, and three Graphene Flagship partners. The objective was to test the printing of graphene patterns on silicon substrates in zero gravity conditions.

Graphene Flagship partner University of Cambridge pioneered the use of liquid phase exfoliation to prepare graphene and related materials inks. Such inks are now used to print all sorts of devices, ranging from flexible electronic sensors and gauges, to batteries and super-capacitors and many others. Graphene-inks are already on the market, and many Graphene Flagship partner companies and spin-offs are commercializing this technology. This first experiment with graphene in space, led by Graphene Flagship partner Université Libre de Bruxelles, will allow us to better understand the fundamentals of the printing process on Earth, by removing the presence of gravity and studying how graphene flakes self-assemble. Most importantly, these experiments are a first step towards making graphene printing available for long term space exploration, since astronauts may need to print electronic devices on demand to cope with long-term missions. Graphene-based composites may also be used to offer radiation protection, another compulsory requirement to enable manned space explorations, for example during Mars-bound missions.



The MASER14 rocket taking off from Esrange Space Center. Credit: Christophe Minetti, ULB

This research follows the zero-gravity parabolic flight campaign that took place in May 2018. The earlier experiment enabled 24 seconds of microgravity to test these same properties and the quality of graphene dispersions prepared by Graphene Flagship Partner University of Cambridge.

Taking this research a step further, the flight of the MASER 14 rocket launched 250km above the Earth surface from Esrange, Sweden, enabling more than six minutes of microgravity, giving researchers additional time to carry out their tests, which will validate graphene's self-assembly properties.

"Testing the evaporation of droplets seeded with graphene is an important step towards the comprehension of phenomena involved in coating technologies and energy applications and an enabling factor in the commercialisation of this material for creating a new life-support ecosystem in future human space exploration," explained Carlo Iorio, leader of the space activities carried out by the Graphene Flagship, and a researcher at Graphene Flagship partner Université Libre de Bruxelles. "There is no better way to validate graphene's potential than to send it to the environment it will be used in," added Iorio.

"Graphene has unique conductivity properties that scientists are continuing to take advantage of in new processes, devices and in this case, coatings. Experiments like these are fundamental to graphene's success and integral for building the material's reputation as the leading material for space applications," he says.

The importance of space exploration for the Graphene Flagship is underlined by the organisation of the second workshop in collaboration with ESA at Graphene Week 2019. This workshop, chaired by Carlo Iorio, will cover a variety of topics, all of them related to new graphene devices and technologies that will boost human space exploration.

Andrea C. Ferrari, Science and Technology Officer of the Graphene Flagship and Chair of its Management Panel, explained that "thanks to the expertise in microgravity research of the Université Libre de Bruxelles, the Graphene Flagship has pioneered the exploration of graphene for space applications since 2017. With three microgravity campaigns in parabolic flights already concluded (and a fourth one on the way) this rocket launch is the next step towards our major milestone: bringing graphene to the International Space Station."

“ These experiments in zero gravity have already resulted in patent applications, as well as in the interest of large companies, such as Leonardo. Space is the limit for graphene. Or, is it? - Andrea C. Ferrari ”



Left to right: Carlo Iorio, Andrea Ferrari and Daniele Mangini discuss the experiment. Credit: Graphene Flagship



Carlo Iorio (right) presenting the plans to David Parker (left), ESA's Director of Human and Robotic Exploration. Credit: Graphene Flagship

Car of the Future

CURRENT RESEARCH AND TRANSFORMATIVE TECHNOLOGIES FROM THE GRAPHENE FLAGSHIP ARE DRIVING DISRUPTION WITHIN THE AUTOMOTIVE INDUSTRY

By Melanie Lawson and Vincenzo Palermo

ENERGY EFFICIENCY

Increased energy extracted from new-generation solar cells, enhancing vehicle performance and efficiency.

ROBUST COMPONENTS

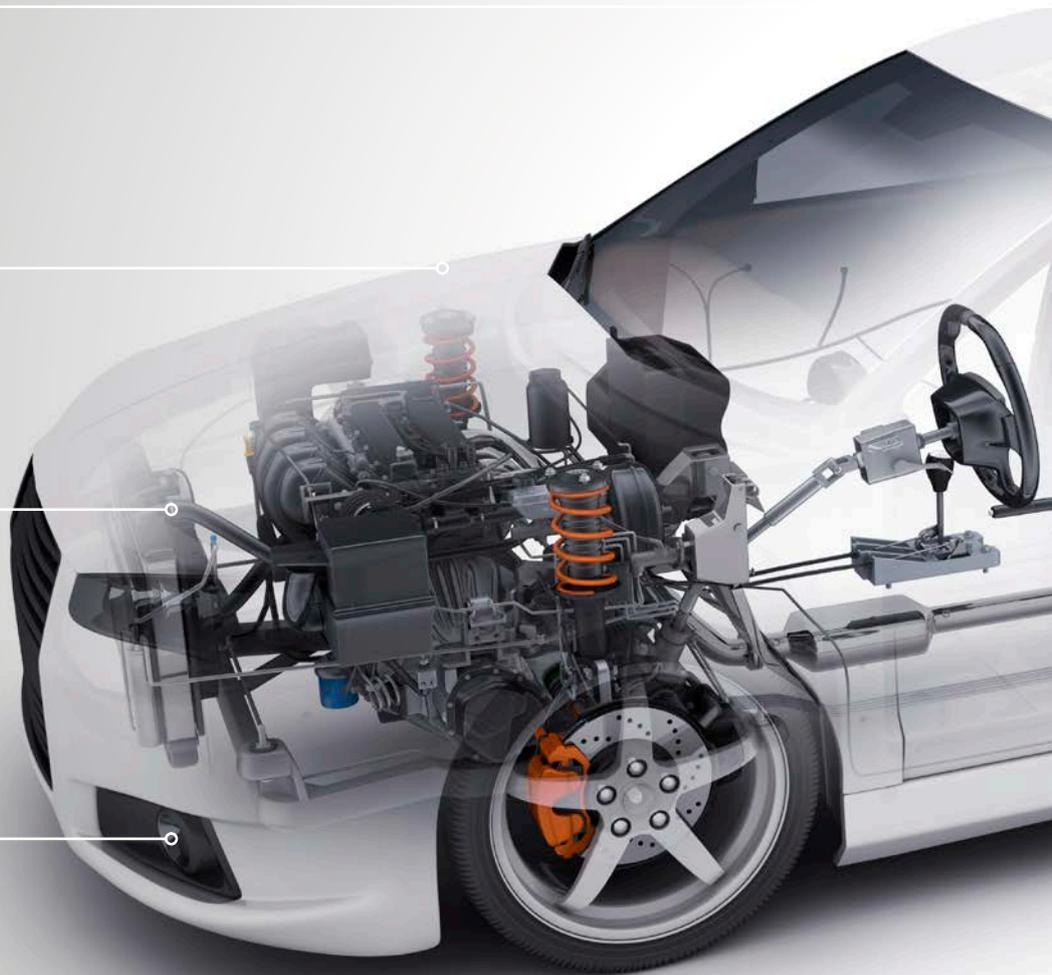
Panels manufactured using graphene carbon fibre composites are light-weight and stronger than traditional panels.

HEAT DISTRIBUTION

Loop heat pipes, previously only tested for aerospace applications, dissipate heat in computer electronics or radiators.

SAFER SENSORS

Graphene-based sensors enable the detection of light from ultraviolet to infrared, improving obstacle detection.





SAFER PIPES AND TANKS

Graphene-based resin used for corrosion-resistant tanks and pipes for storage and transport of volatile chemicals.

REDUCED POLLUTION

Smog consuming catalysts are enhanced, and increased levels of CO₂ are captured.

INCREASED MILEAGE

A new generation of lithium-ion batteries with increased capacity and potential.

ENHANCED GRIP

Graphene 2.0 helps to reduce tyre rolling resistance and increases air retention and grip.

Source:



Graphene Flagship Product Gallery

By Melanie Lawson



GRAPHENE MOTORCYCLE HELMET

Researchers from IIT and Italian design company Momodesign incorporated graphene into the exterior shell of this helmet as a coating. This coating allows better distribution of impact force and the excellent heat-conductive properties of the graphene dissipate heat quickly across the helmet, protecting the inner materials from thermal degradation. The result is a helmet with improved thermal comfort and safety.

MOMODESIGN – en.momodesign.com

GRAPHINK

Graphene-based inks give printed textiles added functionality of touch sensors and circuits. Low-cost graphene inks can replace metal inks for printed circuits for a wide range of smart devices. Graphene inks will pave the road to wide availability of flexible circuits and sensors for smart connections and the Internet of Things.

GrapheneTech – graphene-tech.net



CORSA GRAPHENE 2.0

Corsa is the tire of choice for professional riders in the peloton. Manufactured with premium cotton casing to conform closer to the road's surface, and to provide a smoother ride, easier rolling, and better grip. Four compounds in the tread (4C) and GRAPHENE 2.0 allow for higher speed, increased wear life, lower resistance, and improved grip.

Vittoria – vittoria.com/eu/

EL-ACU-1000 AIR COOLING UNIT

The Elesia Air Cooling Unit EL-ACU-1000 features an innovative approach in the design of high-performance air conditioning. Nanesa produced the evaporator and condenser unit through modern nanotechnology, using aluminium foam slices covered with a graphene-copper coating. These two components act as heat sinks, resulting in a compact system with exceptional efficiency ($\eta > 150\%$, compared to conventional systems).

Nanesa – nanesa.com



GXT-COATING

GNext is able to apply a thin multilayer coating of graphene over a wide range of polymeric films, achieving different degrees of transparency. Our versatile system is compatible with continuous production using industry-level techniques. The thickness of the graphene multilayers ranges from 10 nm to tens of microns, is uniform on a large scale, and stable in harsh conditions of temperature and pressure.

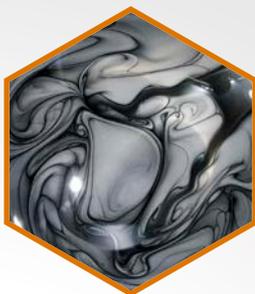
GNext – graphene-xt.com

GXT-ESD

GNext has developed a unique technology that enables the production of ESD bags for electronics devices with graphene. Replacing metals such as aluminium with graphene allows the bags to be recycled as pure polymer. Environmental and economic costs of those products are increasing, but with greener processes, it is now possible to save money and make a sustainable investment.

GNext – graphene-xt.com





GRAPHENE INKS

Cambridge Graphene uses a scalable production process for its graphene ink, developed at the Cambridge Graphene Centre, University of Cambridge. The process allows for a range of ink formulations to be manufactured in order to meet the requirements of different printing methods and substrates. Currently, all Cambridge Graphene inks are aqueous, environmentally friendly and non-toxic.

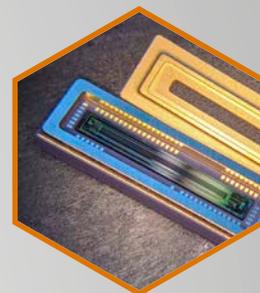
Cambridge Graphene – cambridgegraphene.com

(VIS-SWIR) LINEAR ARRAY DETECTOR

Emberion introduces a novel cost-competitive graphene-based linear array sensor with tailor made CMOS read-out circuits. The product detects Vis-SWIR spectral range (400 – 1800 nm extending up to 2000 nm) designed primarily for spectrometers.

The 512 x 1-pixel linear array provides consistent responsivity with very low noise and high dynamic range over a broad spectrum.

Emberion – emberion.com



NEUTRON

The Neutron is the first roll to roll system capable of depositing large area graphene onto metal foils under ambient conditions. Since the Neutron does not require a vacuum, it can be easily placed inline at manufacturing, enabling truly cost-effective graphene production.

Aixtron – aixtron.com/en

CCS

The CCS is the reactor of choice for leading universities, R&D institutes and industry for growing world-class 2D nanomaterials. The platform uses AIXTRON's scalable shower-head and heating technology to enable the growth of 2D materials onto wafers without requiring a catalyst.

Aixtron – aixtron.com/en



MEDIADEVIL CB-01 EARPHONES WITH NANENE GRAPHENE ENHANCED AUDIO

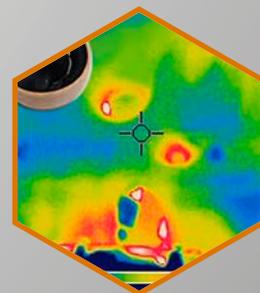
MediaDevil's CB-01 earphones, compatible with any 3.5 mm connector jack port, are manufactured with a graphene coating called Nanene® Graphene-Enhanced Audio. Nanene enables the production of an earphone diaphragm that is thinner and more flexible than one from traditional materials, enhancing both the high-end (treble) and the low-end (bass) of the audio frequency wave.

Versarien – versarien.com

AVANGRM-RUBBER: THERMAL DISSIPATION FOR RUBBER

AvanGRM-rubber integrates graphene materials with rubber; a polymer with traditionally low levels of thermal conductivity. The use of graphene in rubber-based components, such as housing in automotive components, increases heat dissipation and ultimately results in higher thermal conductivity, greater product shelf life, and improved performance.

avanzare – avanzarematerials.com



Bringing Graphene and New Materials to Market

By: Kari Hjelt, Graphene Flagship Head of Innovation and Thomas Reiss, Work Package Industrialisation Leader

Remember the computer triode? Unless you're an early-tech enthusiast, it's unlikely. Used as switches in the first electronic computers, these vacuum tubes consumed a great deal of power. They were unreliable, and upon the invention of silicon chips, were quickly replaced. Similarly, graphene has the potential to shift entire industries.

Graphene, a material that is just a one atom thick, has exceptional physical properties. With a budget of €1 billion and initial period of ten years, the Graphene Flagship is one of Europe's biggest research initiatives, aiming not only to continue developing graphene in academic laboratories, but also to spearhead efforts for the commercialisation of graphene, preparing for its widespread adoption in industry.

Halfway through the ten-year project, the Graphene Flagship has successfully developed over 25 commercial products, using the impressive conductivity, strength and flexibility of graphene to improve on the properties of previously existing materials.

However, bringing a new material to market is not without its challenges.

Historically, it takes an average of 30 years to take a material from its invention into the commercial realm. Low cost aluminium, for instance, was first isolated in 1824, and for a while during the 19th century it was more expensive than gold and considered a very luxurious metal. Aluminium wasn't widely used until an affordable manufacturing structure was set up in 1886, and it didn't become popular until the early 1900s. Materials that experienced similar time lags in their adoption include titanium, Teflon, Velcro and polycarbonate, a plastic material used in the manufacture of bulletproof glass.

Careful planning is essential in the phase when research and commercialisation start to overlap. Particularly due to the sharp contrast between the languages that are used in academia and industry. To ensure this process runs smoothly and successfully, a key driver is the establishment of efficient networks between both worlds. The Graphene Flagship has done this through a core consortium of over 150 academic and industrial groups. Around 40% of the current members are companies aiming to incorporate graphene into their products.

More recently, the Graphene Flagship established a new kind of working group among its consortium – the spearhead projects. These projects, led by key industrial partners, will boost the technology readiness level (TRL) of major technologies in European industries, such as aviation, automation and energy generation and storage.

Thanks to this multidisciplinary network, the Graphene Flagship envisioned the Graphene Technology and Innovation Roadmap (graphene-flagship.eu/project/roadmap) — an expected timeline for the adoption of graphene technologies. The roadmap focuses on fundamental industry areas, such as electronic devices, photonics, sensors, energy conversion, energy storage and biomedical devices.

The Graphene Flagship's principal mission is to take technologies based on graphene from the laboratory to commercial application. During our first phase, we continued to witness the potential of graphene-based technologies to create market disruptions and transformational innovations.

In our next phases we will continue to move from materials research towards component development and system-level integration. Our focus is in combining technology



Graphene Flagship Head of Innovation Kari Hjelt



Graphene Flagship Work Package Industrialisation Leader Thomas Reiss

push and market pull by working with industry stakeholders to increase technology readiness levels.

The Graphene Technology and Innovation Roadmap predicts that graphene for use in flexible perovskite solar cells, high frequency electronics and supercapacitors for warehouse logistics is likely to occur in the next five years. Later technologies, including bioelectric medicine and 6G wireless networks may take a while longer, with estimated adoption in 2030 and beyond.

On top of that, the Graphene Flagship has established two new services for the validation and standardisation of graphene and related materials, which will be of outstanding utility for industries looking into incorporating graphene into their products. So far, the absence of accurate measurement protocols and the lack of standards have become a serious obstacle to the commercialisation of graphene and related materials. The Graphene Flagship enabled professional validation and standardisation processes – provided by national measurement institutes renowned for their excellence, integrity and impartiality –

that will accelerate the technology development and transfer to industry.

“ Bringing a new material to market cannot be rushed, but when managed properly, can yield incredible results. ”

Soon, the Graphene Flagship will also release an open access publication that gathers all the know-how in the manufacture of graphene and related materials acquired during years of basic research. Encompassing over 1,500 references and the knowledge of over 70 co-authors from the Graphene Flagship consortium, this publication will provide a single source of knowledge on graphene and other layered materials.

There were 124 years between the discovery of silicon in 1824, and the creation of the silicon chip in 1958. Now, arguably the most influential invention in computing so far, this chip technology is used in almost all modern products.

INNOVATION IN FOCUS AT GRAPHENE WEEK

Innovation and commercialisation, based on a core of world leading science, is what drives the Graphene Flagship. This year it also drives Graphene Week with the Graphene Innovation Forum, spread over three days focusing on Wearables, Datacom & 5G and Energy along with the addition of the Business Networking Lounge.

The **Graphene Innovation Forum** aims at strengthening ties between Graphene Flagship researchers and industry stakeholders to enable the increase of graphene's technology readiness level. Each day of the Graphene Innovation Forum has a dedicated theme, with Wearables on Monday, Datacom & 5G on Tuesday and Energy on Wednesday. Each session starts with a presentation of the latest results from the Technology and Innovation Roadmap, which was created by the Graphene Flagship to see more clearly the path of graphene to commercial success and will be focused on the session's application area. Following this, the latest results from the Graphene Flagship's application orientated spearhead projects will be presented.

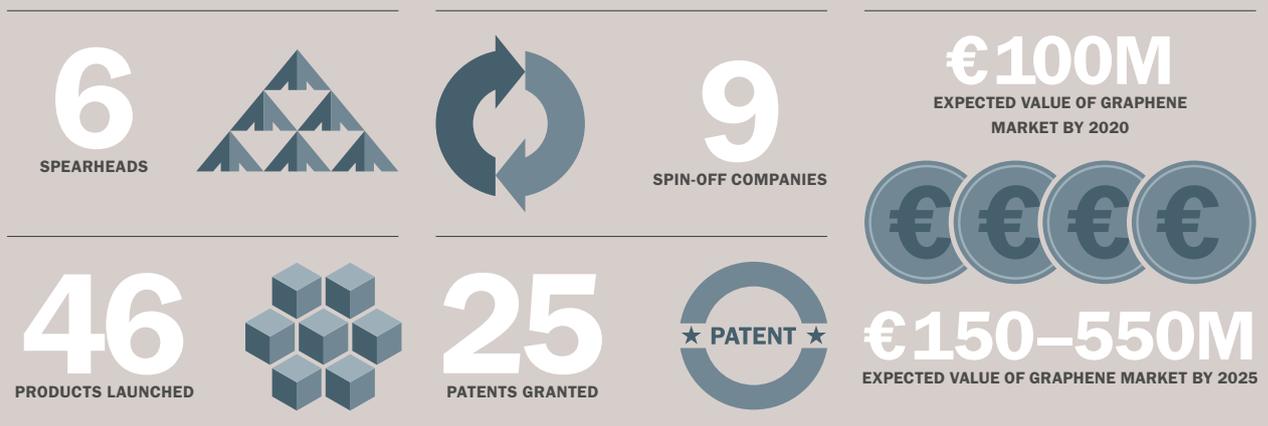
This year, for the first time, Graphene Week has a dedicated **Business Networking Lounge**. Graphene Week attendees are encouraged to use this space to meet and discuss anything related to graphene's commercialisation. In this space you will also easily be able to arrange meetings with the Graphene Flagship's Business Developers, if you are interested in commercialising your research or understanding more about how graphene could help solve problems for you company this is a good place to start.



ROADMAP



GRAPHENE FLAGSHIP INNOVATION BY THE NUMBERS



Unlocking Thousands of New Materials

By: Mar García-Hernandez, Graphene Flagship Work Package Leader

When it comes to nanomaterials, recent experiments have shown that layering several elements can be a formula for magic.

Before realising the potential of graphene and related materials (GRMs), the term was used to describe single layer nanomaterials that could be integrated with graphene.

Graphene describes a single monolayer of graphite. Tightly bound in a hexagonal honeycomb structure, these carbon layers are just one atom in height. This means you'll need to stack three million layers to create graphene just a single millimetre thick.

Hailed as the first ever two-dimensional crystal, graphene is noted as a super-material because of its unrivalled strength, conductivity and light weight. Since its isolation in 2004, a discovery which achieved the Nobel Prize for Physics, the nanomaterial has made headlines, but it isn't the only single layer material with exceptional properties.

Graphene's isolation paved the way for a new class of crystals to be discovered, all of which are one atom thick. In fact, researchers at the Graphene Flagship have now identified between 2,000 and 5,000 new materials that can be exfoliated to a single monolayer. While these GRMs may not boast the exact properties of graphene, combining these materials has the potential to change the world.

Due to their atom-scale structure, GRMs can be shuffled with each other to engineer new materials on demand. The integration of GRMs in perovskite solar cells are a good example of this.

Perovskite cells, a material increasingly used in solar panels, are most effective for power generation when used in small areas. However, large scale perovskite operations have difficulty consistently depositing solar cell layers, leading to reduced energy generation and difficulties scaling up this technology.

In a Graphene Flagship project, two different GRMs were added to perovskite cells to boost the connectivity between the perovskite and the electron-collecting titanium dioxide (TiO₂) layer. This was achieved by mixing graphene flakes into the TiO₂ layer and adding a separate layer of lithium-reduced graphene oxide between the perovskite and the TiO₂.

Introducing these GRMs enabled record-breaking renewable power generation for the cells, achieving a 12.6% conversion rate. While the process of integrating these materials is incredibly complex, it's easy to understand how the results could impact our day-to-day lives.

Layering is a more complex process than it may appear, however. Scientists are also experimenting with different parameters while piling up layers. Among them, the angle between the atomic arrangements of the various layers is of paramount importance to setting the materials' properties. This follows a discovery made in 2018, which identified that graphene could become a non-resistive superconductor when successfully twisted at a 1.1-degree angle.

When attempting the experiment, scientists discovered that the smallest error in alignment could give entirely different results. For GRMs, this means that twisting each atom layer has the potential to open the floodgates for a huge number of new materials.

Graphene Flagship research has already identified numerous possibilities for GRM structures and manipulations, the results of which are already playing functional roles in industrial applications.



Introducing GRMs to perovskite solar cells enabled 12.6% power generation for the cells.

Profile:

Mar García-Hernandez

By: Rebecca Waters

Mar García-Hernandez of the Spanish National Research Council (CSIC) is the leader of the Graphene Flagship Work Package Enabling Materials, which is focused on development of scalable synthesis methods for graphene and other layered materials.

Graphene Flagship: How did you first become interested in science?

Mar García-Hernandez: I was studying humanities in high school and wanted to become a philosopher. After visiting a series of university lectures, I found that philosophy was much too subjective for me. The scientific method and its grounding in facts appealed to me more. I went on to study Chemical Physics followed by a PhD in Molecular Physics. In my first post-doc I started working in Experimental Condensed Matter Physics, and I still do.

GF: How did you get involved in graphene research?

MGH: I was already working on 2D materials, specifically the physics of interphases between interfacial layers, and I was aware of the effect of 2D materials in a physical system. When graphene was isolated, I thought it made sense to pursue this field.

GF: How did you come to join the Graphene Flagship?

MGH: When the Graphene Flagship launched, I realized that Spain had a great potential for contributing to the project. The companies Graphenea, Antolín and Avanzare already made Spain one of the largest producers of graphene. There were also big companies like Repsol or Airbus genuinely interested in graphene. I saw the project



as a great opportunity and took the lead in the Spanish graphene community.

GF: What is your favorite thing about your work?

MGH: The best thing about science is that you ask questions, form a hypothesis, and then you have a very good chance of finding a solution. With graphene it was a whole new era, the material posed new challenges and suggested a lot of new questions. The synthesis of graphene was a new field with a horizon that was so astonishing and so broad that it was very encouraging.

GF: What is your favorite property of graphene?

MGH: The morphology of graphene, the fact that it is the thinnest material in the world is truly amazing! Beyond that, the electronic properties of graphene as defined by the Dirac equation are incredible because of the many possible applications created by charge carriers in graphene that have an effective speed comparable to the speed of light.

PRODUCTION AND PROCESSING OF GRAPHENE AND RELATED MATERIALS

Graphene is already being used in many commercial applications, with numerous new products on the horizon. However, a lack of information on the correct preparation and processing is hindering its uptake. To tackle this challenge, Graphene Flagship researchers have produced a comprehensive guide entitled “Production and Processing of Graphene and Related Materials”, which has been published by IOP Publishing in their journal 2D Materials.

The article condenses the knowledge acquired and developed by the Graphene Flagship over the past five years, encompassing more than 1,500 references and the knowledge of 70 co-authors from the project’s partners and associate members. With this publication, the Graphene Flagship will make this knowledge public as part of its long-term goal to assist in the development of other materials.

The article provides a comprehensive guide on the techniques for production and processing GRMs, as well as the key characterisation procedures. It is aimed both at expert academics and beginners, as well as companies that would like to experiment with GRMs and incorporate them into production and product design.

“The article encompasses the description of the most popular methods to produce GRMs,” explained Mar García-Hernandez, work package leader at the Graphene Flagship. “It also describes some of the technological problems users might encounter, such as the processing of inks and the transfer of materials, as well as the characterisation.”

Learn more about this publication at Graphene Week in the “Publishing Collaboration for the Graphene Flagship” session chaired by IOP Publishing being held Thursday 26 September at 14:30.

JOIN THE GRAPHENE FLAGSHIP COMMUNITY

APPLICATIONS FOR ASSOCIATED MEMBERSHIP
ARE ACCEPTED CONTINUOUSLY



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Benefits of Membership

- Collaboration with Graphene Flagship Members
- Exhibition Exposure
- Industrial Workshops
- Marketplace: Showcase Your Company's Graphene Work



www.graphene-flagship.eu

Wearable Technology Seeks New Materials to Enhance Functionalities

By Antonios Oikonomou, Graphene Flagship Business Developer for Wearables and Optoelectronics

Created in 1780, the world's first pedometer was developed using an earlier mechanism of a self-winding watch. Technology to ensure we meet those all-important 10,000 steps has come a long way since then, but the wearable technology market for health and fitness is constantly looking for new materials, to continue development and innovation.

Dubbed as the 'year of wearables', 2014 witnessed a surge in wearable technology for health applications and, since then, the rate at which products are released has not slowed down. According to a report by Euromonitor, units of wearable technology are projected to exceed 305 million by 2020, with a compound annual growth rate (CAGR) of 55%.

Health and fitness are amongst the most successful application areas for wearable technology. Research by Gartner states that worldwide shipments of wearable devices will reach 225 million in 2019, an increase of 25.8% from 2018. However, despite an increase in sales,

the technological advancements of wearable healthcare devices have decelerated.

Take fitness tracking as an example. While there have been a huge number of products released, such as smart watches, activity bands and clip-on trackers, there has been little development in technology beyond style, design and aesthetics.

“ Smarter wearable devices, such as those that can be weaved into clothing, implanted in shoes or concealed on the wearer's skin, are only now being developed into marketable products. ”

For instance, Graphene Flagship partner ICFO designed a wearable health tracker, that is flexible, transparent and disposable, rather than a typical watch-style design. This patch has the potential, in the future, to accurately monitor several aspects of the wearer's bodily functions,



ICFO's wearable health tracker is flexible, transparent and disposable.

including heart rate, hydration, oxygen saturation, breathing rate and temperature.

As a smaller device, it would be easy to assume it is less powerful than its wrist-based predecessors. However, by using optical sensors exploiting graphene, the transdermal fitness patch surpasses the current limitations of existing fitness trackers, with improved accuracy. This is thanks to a combination of optoelectronic and mechanical properties.

Gait analysis, another area of fitness which is already using wearable technology, is also being improved with the integration of graphene. Pressure sensing insoles are not a new phenomenon. However, lightweight graphene-embedded foam could allow for these to be integrated into any type of shoe. This was demonstrated by a prototype developed by Graphene Flagship researchers at the University

of Cambridge, and showcased with an interactive prototype at the 2019 Mobile World Congress, whereby users could control a snowboarding avatar on a screen.

Giving runners greater freedom to use these insoles during personal training, thanks to ease of adding or removing insoles from shoes, this technology could allow for better insight into running techniques. For sportspeople and athletes, this would allow continuous monitoring of any biomechanical abnormalities in their gait cycle, helping to improve technique and avoid injury.

We have come a long way since the early examples of pedometers for counting steps. Wearables for the health and fitness market are in high demand. However, in order to improve their performance and capabilities, product designers must begin experimenting with new advanced materials, such as graphene and related materials.



Antonios Oikonomou (left) is the Graphene Flagship Business Developer for Wearables and Optoelectronics



Pressure sensing insoles made of lightweight graphene-embedded foam could be integrated into any type of shoe.

Women in Graphene

Timed to coincide with the International Day of Women and Girls in Science in February, the Graphene Flagship held the Women in Graphene Career Development Day at the National Graphene Institute in Manchester, UK. This year's two-day event was designed to provide

women working in graphene with networking opportunities, female role models and career development training. The Graphene Flagship award a number of travel grants to early career researchers, enabling six women to attend. Here they share their impressions.

“ One of the highlights of Women in Graphene events each year is the diversity of the speakers. In 2017 there was a brilliant talk by the polar explorer Felicity Aston, in 2018 it was the hilarious Elaine Eksvärd giving excellent advice on combatting suppression techniques, and this year it was the infectiously enthusiastic Jess Wade telling us about her mission to add female scientists to Wikipedia. Each one is refreshing and entertaining, with brilliant and unusual stories to share.



I am very grateful that I received the travel grant and could attend this year's event. It was great to see some familiar faces, but also exciting to see how the event is growing. I left the meeting feeling inspired and motivated, and happy that I am part of such a supportive and nurturing community. ”

HANNAH WATSON, PhD Student, University of Cambridge

“ Laura Norton from the Royal Society of Chemistry presented an updated version of the leaky pipeline in her 'Breaking the barriers' report, which showed that nothing had changed regarding gender balance in chemistry for many years: at the undergraduate level 44% of students studying chemistry are women but this number drops to 39% at the PhD student level and down to 29% at the non-professorial staff. What is even more shocking is that this number then decreases to 9% at the professor level. Sadly these numbers do not only apply to chemistry but are very similar for other STEM subjects, such as physics, computer science, engineering... The percentage of female scientists in leading roles is terrifyingly small.



For me the most important take-home message was the answer to my question to Sarah Haigh after her talk. I asked her how she knew that she was ready for the transition from being a postdoc to being a lecturer and starting her own research group. Her answer was quite simple: She did not know she was ready but said that by the time you know you are ready it is already too late. Just go for it and be confident in yourself and your research. ”

ANNA OTT, Research Associate, Cambridge Graphene Center, University of Cambridge

WOMEN IN GRAPHENE AT GRAPHENE WEEK 2019

Graphene Week will once again host a Women in Graphene workshop. This year's session will be moderated by Jane Powell (BBC, UK). It will feature 30 minute keynote talks by successful graphene scientists Maria Smolander (VTT, Finland) and Mar Garcia Hernandez (CSIC, Spain) followed by a panel discussion. Panellists will include

Vanja Miscovic (University of Brussels, ESA, Belgium), Amaia Zurutuza (Graphenea, Spain), Zina Cinker (National Graphene Association, US) and Stephan Roche, ICN2, Spain. A wine reception will close this Women in Graphene session, providing a great opportunity to network with women in science.

“ The meeting was closed with an insightful talk by Jess Wade (research scientist at Imperial College London), who has been the subject of media attention due to her contributions to female scientist’s visibility through the creation of Wikipedia pages outlining their careers and research topics.



Jess touched on some of the barriers faced by women in science and added some additional topics for consideration, such as imposter syndrome (in which the sufferer unjustifiably doubts their accomplishments and feels somewhat like a “fraud”), unconscious bias and lack of recognition. It was highlighted that, in studies which scientists were tasked with reviewing applications on scientific content alone (not the CV of the primary investigator) any gender bias was eliminated.

Therefore, with the ‘breaking’ of such gender bias barriers, it can clearly be seen that women have much more to contribute to the sciences. ”

SOFIA MARCHESINI, Higher Research Scientist, National Physical Laboratory

“ The career development session from Springboard Consultancy was incredibly helpful in helping us to think about how other people see us as individuals and how we would like to portray ourselves.



The importance of first impressions and our brand were emphasised and something I feel we will all be working on in future. When a question arose about knowing the right time to apply for a job, the response was that we should be applying before we feel we are ready. This is known to be a key difference with how men and women look at the skills needed for a job. ”

ELIZABETH LEGGE, PhD student, National Physical Laboratory and University of Surrey

“ The training on building up networking skills was super useful! I talked to a lot of people and received several nice contacts, which will be very helpful to my current project. Most importantly, I was inspired by learning how important personal visibility is in career development. After the event, I will try to be more active in my professional network. Hopefully I can achieve the small target I set in the career development workshop: to be known by everyone working in my work package in the Graphene Flagship by the end of this year. ”



QIANYE HUANG, Project Engineer, University of Warwick

“ Beyond the feelings of loneliness or inadequacy, what I think is difficult for women (and minorities) in science is the lack of role models. It is difficult to project yourself into the future and dare to dream of a career path when you cannot identify with any of the people you see holding these positions. The Women in Graphene meeting was for me an opportunity to meet successful women in the field. It was really uplifting and gave me more motivation to continue on the path I have chosen. What I also enjoyed was the relaxed atmosphere. We had the chance to share our experiences and be ourselves without fear of being judged or misunderstood. ”



ILHAME KIHAL, PhD Student, University of Cambridge

The Graphene Flagship's Validation Service

– Providing Confidence in Graphene and Related Materials

By Siân Fogden

The Graphene Flagship has launched a new Quality Assurance Programme for graphene and related materials (GRM). The Graphene Flagship's Validation Service – independent and impartial – has been developed by its consortium partners, none of whom is involved in graphene production: National Physical Laboratory (NPL), Universidad de Zaragoza, and Laboratoire National de Métrologie et d'Essais (LNE). The aim of the service is to provide confidence in graphene and related materials to enable a quicker transition of graphene products to market. The service is available for the Graphene Flagship's partners free of charge and for clients beyond of the project at a market price.

Graphene and related materials (often known as two dimensional materials) have many and varied potential applications, from enhanced composite materials through to the next generation of datacom technology. The cornerstone of all of these applications sits with a confidence in the material itself. The expectation is high that the remarkable characteristics of graphene and related materials achieved in leading laboratories will be used to enhance materials and develop new devices. However, this needs to match the level of confidence in the real material produced in different forms. This is a difficult task. The ability of industrial consumers to thoroughly compare the different graphene and related material products on the market to find the one that will fulfil their needs is something that cannot currently be achieved with any level of reliability due to the many and varied characterisation regimes.

Currently there are many different processes used to assess a graphene or related material sample, making it complicated for developers to benchmark and improve their products, and for industry to choose the correct one with any confidence. The ability to provide this confidence is vitally important in enabling graphene and related materials to move from the laboratory and into industry.

Ensuring that graphene and related materials move towards a higher Technology Readiness Level (TRL) is the clear goal of the Graphene Flagship and one that can only be achieved when industry at all levels has the confidence to explore graphene in their products. Hence, the Graphene Flagship's Graphene Validation service was created. This service was born out of a clear need, identified by the work of the Graphene Flagship's Characterisation and Industrialisation group. At its core this validation service provides characterisation of graphene and related materials samples using authorised national measurement institutes and facilities that are world renowned for their excellence, independence, integrity and, importantly, impartiality.

To provide as wide a range of measurements as possible, this validation service is comprised of three laboratories (National Physical Laboratory, Universidad de Zaragoza and Laboratoire National de Métrologie et d'Essais) from three different European countries (UK, Spain and France). It offers a range of measurements from structural, mechanical, optical, thermal, electrical, magnetic, chemical and lifecycle of bulk composites; all in an independent and impartial manner.

"Validation is about providing documentary evidence with a defined standard operation procedure and internal processes. Through this we hope to provide an enhanced level of confidence within the graphene industry," said Alexander Tzalenchuk, Fellow of National Physical Laboratory. "This level of materials characterisation can be prohibitively expensive for small companies and through our service we aim to offer this comprehensive testing at an affordable level. This service can be thought of as outsourced Quality Control which has the simple aim to help speed up getting materials, devices and systems to market."

VALIDATION SUCCESS

30%

OF ALL INTERNATIONAL GRMS-RELATED
STANDARDISATION PROJECTS ARE LED BY EUROPE

23

VALIDATION REQUESTS



80%

OF THESE HAVE BEEN INITIATED BY
GRAPHENE FLAGSHIP MEMBERS

SERVING

9

WORK PACKAGES



“The service itself was initially developed using graphene composite materials, where standards are in existence already,” said Tzalenchuk. “We are currently developing the service further to cover graphene and related materials powder, inks, suspension and coatings. As the TRL of the Graphene Flagship increases, the offering of the validation service will become more sophisticated. Now we are focusing on validating materials, but in the future this could be expanded to devices and systems.”

“The Graphene Flagship enabled work on standardisation by bringing people together in a collaborative working environment. From the start the Graphene Flagship saw the need for a characterisation work package which evolved with the project into an industrialisation work package, and from that the idea for the validation service was formed,” said Raul Arenal, ARAID researcher in the Instituto de Nanociencia de Aragon at the Universidad de Zaragoza.

““ The creation of the Validation Service is a great advance in the ambition of the Graphene Flagship to turn graphene science and technology into industrial success. ””

“In the service, we do not perform just characterisations, we perform measurements in a solidly established framework of references. This is essential to give confidence to all stakeholders (researchers, industry, consumers). This role comes from our mission and our experience of

accredited national measurement institutes or facilities. For the requests where standards are lacking, we are inspired by existing well-established and rigorous measurement protocols and these dedicated developments feed the standardisation process. Actually, we are also used to working with standardisation bodies. Finally, our measurements are expected to contribute to the assessment of both performance and risks of materials and products based on graphene and related materials,” said Félicien Schopfer, researcher at Laboratoire National de Métrologie et d’Essais.

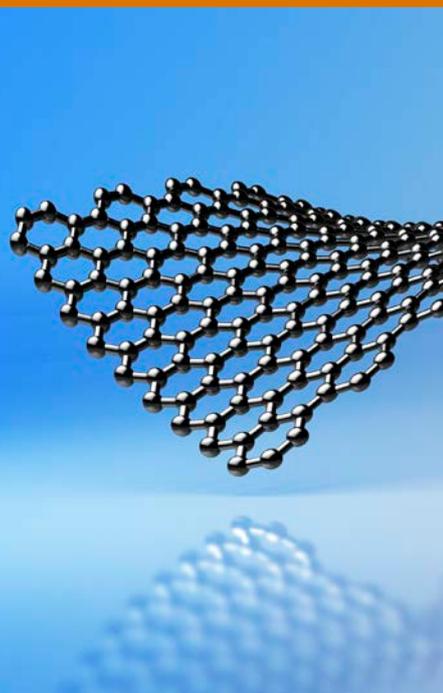
As Oihana Txoperena, a research scientist at Graphenea commented: “The Validation Service provided by the Graphene Flagship is a very useful resource for accessing characterisation techniques which are not available in-house. The service is fast, experts are very professional and always ready to help and the reports are excellent.” The Graphene Validation service is open for submission of samples to their bulk composite measurement service. As part of this service samples can be tested using qualified techniques with the best techniques chosen for each sample to produce the required range of validations out of a current list of 84.

“As well as looking at graphene, the service is already providing measurement on related materials such as tungsten disulphide, indium selenide and van der Waals heterostructures, with many other materials being considered,” said Graphene Flagship Science and Technology Officer Andrea C. Ferrari.

DISCLAIMER:

The Graphene Flagship provides the Validation Service to accelerate the industrialisation of Graphene and Related Materials (GRM). The service is provided by authorised national measurement institutes and facilities renowned for their excellence, independence, integrity and impartiality. Clients receive a detailed report, which is specific to a validated sample and provides documentary evidence demonstrating selected characteristics of that sample as requested by the client. The measurements adhere to available standards or established procedures. The validation service report can be used by clients to establish specifications, to find reliable suppliers, for benchmarking according to industry Figure of Merit (FOM), and to promote the end-product with GRM. The report must be referred to in full where it is used for promotional activity. No standard price list is available, the process is designed individually for each validated sample:

- Graphene Flagship’s Consortium partners are eligible to get the service free-of-charge while the EC’s grant budget is available.
- Graphene Flagship’s Associated Members and Partnering Projects are able to get the service on cost-based conditions.
- The service is accessible for non-Graphene Flagship community on a commercial basis.



Phyphox – Physical Phone Experiments

By Melanie Lawson

BEHIND PHYPHOX

The Phyphox App came to life as a motivational tool for students of the lecture “Experimental Physics 1 – Mechanics”, at RWTH Aachen, in 2015. Inspired by existing apps that access the phone’s sensors, lecturers wrote a custom app enabling students to perform their own experiments alongside the lecture. The full potential of Phyphox was quickly realised and the creators began to develop the concept with the vision of a broader audience, releasing the first version in 2016.

Phyphox was no longer a tool specific to a single lecture at RWTH Aachen but a tool employed by academic institutions globally.

Teaching and experimentation in Physics is often assisted through smartphone technology, though many experiments are inhibited by practical issues. Typically, the device is inaccessible during an experiment and data analysis is usually completed subsequently on a computer, but with Phyphox both problems are addressed.

SENSORS

Phyphox transforms your smartphone into a mobile science lab; utilising existing sensors contained within your device. Phyphox provides access to the sensors in your phone either directly or via a selection of pre-programmed experiments, ranging from using your phone as a pendulum to measure the earth’s local gravitational acceleration, to a live doppler effect demonstration. The range of sensors utilised, including a barometer, gyroscope and microphone, make interactive physics experiments possible by eliminating the traditional boundaries of the classroom.

DATA ANALYSIS & REMOTE CONTROL

Sensors capture data from our surroundings which can be monitored in real time or exported as raw data for further analysis. Students are able to gain practical experience in data acquisition and interpretation; a fundamental skill in our technology-centric world.

The versatility of Phyphox extends to remote-control functionality, enabling users to control the experiment through any device connected to the same smartphone network – simply copy the URL from your device into your web browser.

CUSTOM DESIGN

Users wishing to test the limits of Phyphox can create custom experiments using the visual experiment editor function. The editor generates a simple file that defines your experiment including data analysis, which can then be shared with students or colleagues to perform. This custom experiment feature provides endless possibilities, though users are advised to first watch the tutorial provided as this function is relatively complex.

USER FRIENDLY

For a physics novice, Phyphox offers a pre-defined database of investigations and simple help sections, whilst more common experiments include a video tutorial. The clear organisation of this user-friendly app means that complex smartphone-based experiments are accessible to anyone keen to uncover the laws of nature.

THE FUTURE OF PHYPHOX

Three years after the public release of Phyphox, with more than 700,000 installations on Android and iOS, developers at RWTH Aachen are certain the app has not yet reached its full potential. The creators have plenty of ideas on how to improve the app and work creatively with newly emerging technologies.

Volunteers are currently working on translations in numerous languages, which is essential to use Phyphox in an educational capacity, internationally. Moreover, many academic institutions have not yet established digital methods for teaching physics, meaning future demand for the app is predicted to increase further.

Now is the time to uninstall all those games on your smartphone – Phyphox is here to activate your brain!



Phyphox captures data using the existing sensors within your smartphone to enable interactive physics experiments.

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