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

Helsinki, Finland
23 – 24 September 2019

Workshop report

Workshop chairs: Dr Ken Teo (United Kingdom), Professor Dusan Losic (Australia)

Contents

Overview

The 2nd Graphene Flagship – Australia Workshop was held at the Marina Congress Centre in Helsinki (Finland), during 23-24 September 2019. The workshop was organised as a parallel session of the Graphene Week 2019 conference and gathered numerous attendees of the conference. The feedback of Australian delegates has been very positive as they could benefit also from the networking opportunities of the Graphene Week 2019 conference.

The workshop provided an open technical forum that brought together leading researchers from Europe and Australia to discuss cutting-edge research in 2D materials, with the aim to facilitate scientific exchanges, discuss common challenges and explore mechanisms for future collaborations. This workshop was a follow up to the 1st Australia-EU Workshop held on 17-19 October 2018 in Adelaide and Sydney (Australia).

The main topics addressed during this workshop were graphene production and functionalization, composites, filtration, energy, fundamentals, sensors, commercialisation and certification.

The workshop first covered production of graphene and composites in different forms. Latest research outputs from Australia and the Graphene Flagship were presented. The development of products incorporating graphene were featured, such as fire-retardant paint (on the market already since this year), strain-sensors embedded in composites for structural and sports-applications, a rudder for the Airbus A380 and an automotive oil pan for CR-FIAT. Graphene and graphene oxide membranes for water filtration was also commercially being developed into a product. On the energy front, an innovative spray gun technique for the deposition of graphene was used to produce supercapacitors.

On the second day, the focus was on fundamentals, followed by commercialization and validation of graphene-related materials. Heterostructures of 2D materials was discussed for their optoelectronic properties. New findings explaining the mechanisms behind the instability of WS2, a particular 2D material, was shown and how to mitigate this. The widespread availability of graphene material and differing published properties has resulted in need to create of validation laboratories. Graphene certification Labs (Australia) and NPL (Graphene Flagship) are both facing the challenges of standardizing the certification protocol for graphene-related materials, and providing then the validation service to graphene users and suppliers. Another important topic covered for commercialising graphene/business development were the challenges in technology transfer between academy and industry.

The participants also had an informative visit to VTT, which is the leading research and technology institute in the Nordic countries, and in particular, their Printed Electronics Lab and MICRONOVA clean room. Several graphene-based printed electronics products developed by VTT were demonstrated. Participants visited also Aalto University and toured their well-equipped Nanomicroscopy Centre and Low Temperature Lab. Participants expressed interest to benefit from the state-of-the-art instruments available at Aalto University for the characterization of graphene related materials.

Visit to VTT and Aalto University

The workshop was co-organised by the European Graphene Flagship project and the Australian Research Council (ARC) Hub for Graphene Enabled Industry Transformation and was co-chaired by:

- Dr Ken Teo (Aixtron, United Kingdom)
- Professor Dusan Losic (University of Adelaide, Australia)

The workshop gathered 15 speakers (9 from Australia and 6 from Europe), from which 4 are from industry. For details about the scientific content of the presentations, see the Speakers and Abstracts section.

This report summarises the main conclusion of the discussions and the envisaged ways for collaborations.

Common challenges and opportunities for collaborations

This year, at the second EU-Australia Workshop, 15 speakers, including representatives from industry, presented a broad range of topics and many common interests came up for future closer collaborations in terms of exchange of students, samples, instruments etc., with the potential to generate joint publications. Much was discussed as well about the importance of certification and quality control of graphene materials as there is a strong need and intention to push this material to higher technology readiness level. For confidence in graphene material and its adoption in the market, certification labs are needed together with standardization of the material and the validation procedures. In the final discussion session, there was clear interest to continue the series of workshops by organising the next workshop in Australia (potentially Melbourne) in 2020. Participants discussed also about potential topics for the next workshop. The format of the 3rd workshop was discussed, and topics will be arranged around solving common challenges and bring close collaboration between Australian and EU researchers. A greater industry involvement in future workshops is also proposed.

In terms of future EU-Australia collaborations, participants welcomed the availability of international grants available for researchers in Australia. Also, from EU side, mobility grants are available under the Graphene Flagship Core 2, which allow young researchers from Europe to perform research stays in laboratories in Australia. This, along with the access to H2020 funds for Australian researchers, could improve the possibilities for future collaborations. Further possibilities could be explored through the participation of ERC/EC representatives in the workshops.

GRAPHENE FLAGSHIP

ARC Research Hub for Graphene Enabled Industry Transformation

Programme

September 23, 2019		
Nordia, 2nd floor		
15:00 – 15:30	**Registration and welcome**	
15:30 – 15:45	*Dusan Losic*	The chemical functionalization of graphene and building their composites for emerging applications
15:45 – 16:00	*Costas Galiotis*	Activities in the area of graphene composites by the Graphene Flagship
16:00 – 16:15	*Browyn Fox*	Incorporating graphene into carbon fibre composites for structural health monitoring applications
16:15 – 16:30	*Jun Ma*	Polymer/Graphene Composites for Strain Sensors
16:30 – 17:00	***Coffee break***	
17:00 – 17:15	*Mainak Majumder presented by Joynul Abedin*	Graphene-oxide membranes: from fundamentals to up-scaling towards commercialization
17:15 – 17:30	*Manuela Melucci*	Graphene oxide enhanced membranes for tap water purification
17:30 – 17:45	*Rakesh Joshi presented by Tobias Foller*	Application of GO/rGO membranes for purification and separation
17:45 – 18:00	*Paolo Bondavalli*	Dynamic Spray-Gun Deposition for energy applications and more
September 24, 2019		
Press Room, 1st floor		
15:30 – 15:45	*Vladimir Falko*	Optoelectronics of 2D materials and heterostructures with Gamma-point band edges
15:45 – 16:00	*Michael Fuhrer*	Oxidation of Monolayer WS2 in Ambient is a Photoinduced Process
16:00 – 16:15	*Vincent Gomes*	Graphene and Carbon quantum-based composites for energy storage and electrocatalysis
16:15 – 16:30	*Jaakko Kaidesoja*	Commercializing graphene sensing solutions
16:30 – 17:00	***Coffee break***	
17:00 – 17:15	*Stephen Hunt*	Challenges with Commercialising Graphene
17:15 – 17:30	*Keith Paton*	Graphene Flagship Validation Service: Providing Confidence in Product Performance

17:30 – 17:45	*Joynul Abedin*	Insights into the exfoliation of graphene and graphene oxide: a quantity control process for achieving desired properties
17:45 – 18:00	*Lachlan Hyde*	Graphene Certification Labs
18:00 – 18:30	*Discussion and wrap up*	
19:30	***EU-Australia Workshop – Dinner (Shelter Restaurant)***	

List of participants

Title	Last name	First name	Institution	Country
Dr.	Abedin	Joynul	Monash University	Australia
Dr.	Antiohos	Dennis	Imagine Intelligent Materials	Australia
Dr.	Bondavalli	Paolo	Thales	France
Dr.	Ciubotaru	Ana-Maria	European Science Foundation	France
Prof.	Falko	Vladimir	University of Manchester	United Kingdom
Dr.	Foller	Tobias	University of New South Wales	Australia
Prof.	Fox	Browyn	Swinburne University	Australia
Prof.	Fuhrer	Michael	Monash University	Australia
Prof.	Galiotis	Costas	FORTH	Greece
Dr.	Giorgio	Joseph	Swinburne University	Australia
Prof.	Gomes	Vincent	Sydney University	Australia
Dr.	Hyde	Lachlan	Swinburne University	Australia
Dr.	Hunt	Stephen	Global Technology Solutions	United Kingdom
Dr.	Kaidesoja	Jaakko	Imagine Intelligent Materials	Finland
Prof.	Losic	Dusan	University of Adelaide	Australia
Prof.	Ma	Jun	University of South Australia	Australia
Dr.	McRae	Jacqui	ARC graphene Research Hub manager	Australia
Dr.	Melucci	Manuela	CNR	Italy
Dr.	Paton	Keith	NPL	United Kingdom
Dr.	Teo	Ken	Aixtron Ltd	United Kingdom
Dr.	Vacchi	Isabella	European Science Foundation	France

Talks and abstracts

The chemical functionalization of graphene and their composites for emerging applications

Dusan Losic [1,2]

[1]*The University of Adelaide, School of Chemical Engineering, Adelaide, Australia,* [2]*The ARC Research Hub for Graphene Enabled Industry Transformation, Australia*

Abstract

The chemical modification of graphene by covalent or non-covalent chemical binding of organic molecule, functional groups, nanoparticles and other nano scale elements is emerging as a versatile approach for tailoring the chemical, interfacial, and electronic properties of graphene materials needed for many applications. In this talk, some of the latest developments form our group showing progress on graphene functionalization using different chemical modification and doping processes including click-chemistry, plasma and their assembly and cross-linking for designing complex 2d and 3D graphene composites, surface gradients, heterostructures, with multifunctional properties used for development of new graphene products and devices for emerging industry applications will be presented and discussed. Their most interesting applications such as multifunctional protective coatings, polymer composites, radiation shielding, sound absorption, fire retardants, sensors, antennas, environmental remediations and additive manufacturing will be highlighted.

Keywords: Graphene functionalization, graphene composites

Acknowledgement: This work is supported from Australian research Council (ARC) with the grant ARC Research Hub for Graphene Enabled Industry Transformation (IH 150100003)

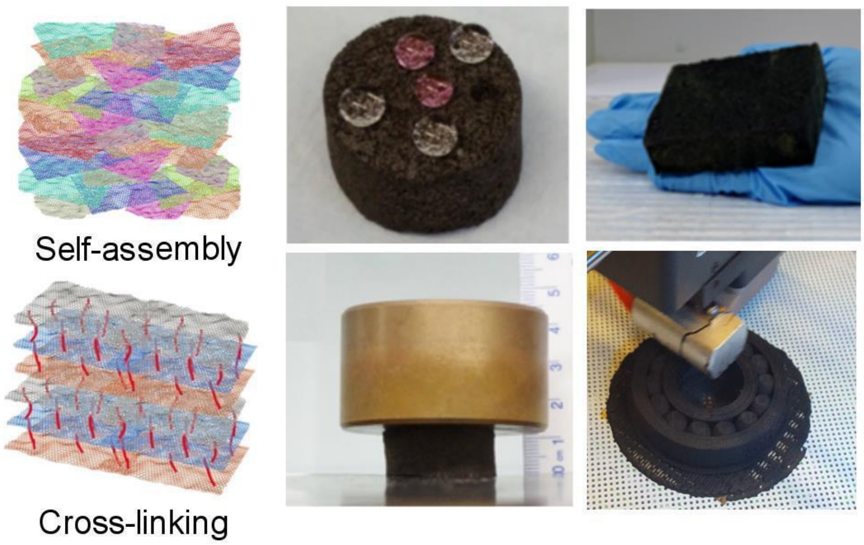

Fig. 1. Functionalization and assembly of graphene structures into 3-d composites with different properties and applications

Activities in the area of graphene composites by the Graphene Flagship

Costas Galiotis [1,2]

[1]FORTH/ICEHT Patras, Greece,
[2]Dep. of Chemical Engineering, University of Patras, Patras Greece

Abstract

This presentation will cover briefly certain activities in the area of composites containing graphene and related materials (GRMs) that are carried out within the Graphene Flagship and in particular by the partners in the Composite

WP14. Overall, the research focuses on the development of high-performance composites for applications in large-scale industries, such as aerospace, automotive and energy generation, and consumer products. Numerous graphene-enhanced multifunctional components and products have been, and are currently, developed for commercial applications. Noteworthy examples of graphene composites applications include: a rudder for the Airbus A380, an automotive oil pan for CR-FIAT, both manufactured by carbon fibre- and graphene-embedded epoxy resin for enhanced performance; a loop heat pipe with graphene coating for heat management improvement in satellite applications and flexible graphene heaters with enhanced thermal stability for a variety of uses. Furthermore, significant progress has been recorded in the transition of GRMs from lab-scale quantities to mass-production, e.g. masterbatches, with new production techniques which will facilitate further expansion of the composites field. Other developments that may have an impact to this area in the near future, such as roll-to-roll automated graphene production and the fabrication of polymer nanostructures will also be briefly mentioned and commented upon.

Incorporating graphene into carbon fibre composites for structural health monitoring applications

Bronwyn Fox [1]

[1]*Swinburne University of Technology, Australia*

Abstract

This presentation describes the incorporation of graphene into carbon fibre composites to create multifunctional materials capable of sensing load changes leading to structural health monitoring applications. Given the increasing number of graphene suppliers and products and the inherent variability, there is an urgent need to understand the relationship between manufacturing, nano-structure, and performance of graphene materials. This should be application specific, ensuring advanced materials containing graphene are sufficiently well characterized to enable proven standards or supply chain management processes can be followed. One of the aims of our current research is to create a globally connected graphene certification centre. This will lead to the de-risking of commercialisation of new graphene enabled technologies

Polymer/Graphene Composites for Strain Sensors

Jun Ma [1]

[1] *University of South Australia*

Abstract

A new fabrication method is presented first for the development of stretchable strain sensors which are based on a composite film consisting of Graphene platelets and silicon rubber. The film has tunable gauge factors 27.7 – 164.5, which can be used as electronic skin, a vibration sensor and a human machine interface controller. Then conventional strain sensors are reviewed for key parameters towards potential impact on new polymer/nanomaterial strain sensors. It concludes that there are no general benchmarks for conventional strain sensors utilized in industry. Challenges are discussed, including reliability, calibration to be used as proper gauges, and soft data acquisition system.

Graphene-oxide membranes: from fundamentals to up-scaling towards commercialization

Mainak Majumder[1], Joynul Abedin[1] & Peter Voigt [2]

[1]*Department of Mechanical and Aerospace Engineering & Department of Chemical Engineering, Monash University, Clayton, Australia*
[2]*NematiQ Pty. Ltd., Notting Hill, Australia*

Abstract

Membranes constructed by stacking atomic layers of graphene-oxide into a self-assembled permeable film has gathered considerable attention in the last few years. Despite many outstanding properties regarding the ability to sieve small molecules and ions in combination with good permeation characteristics, a generic consensus is that these membranes are difficult to upscale and produce in a commercially viable manner. Over the past few years, we have pioneered a novel approach to manufacture these membranes by harnessing the liquid crystalline nature and viscoelastic properties of colloidal dispersions of graphene oxide. We have also demonstrated that structural order in these membranes have an unusual role in enhancing permeation properties – structural order is imposed in the membranes by capillary or shear forces inherent to the membrane formation method. The membranes are stable in a wide range of organic solvents such as methanol, ethanol, acetone and hydrocarbons such as toluene which should significantly improve the application space in organic solvent nano-filtration. Using conventional printing processes such as gravure, we have demonstrated feasibility for translation to a roll-to-roll economical fabrication and real world realization of a low-pressure, low-energy nanofiltration membrane.

(a)

(a) Scaled-up production of graphene-oxide membrane, (b) team-mates demonstrating the scale of production, (c) logo of nematiQ – the commercial partner of this technology, (d) graphene-oxide membrane cartridges for eventual replacement of RO membrane cartridges for point-of-use low pressure, low-energy removal of contaminants.

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Graphene oxide enhanced membranes for tap water purification

Melucci[1], M.L. Navacchia[1], A. Kovtun[1], M. Zambianchi,[1] M. Gazzano[1], L. Bocchi[2], V. Palermo[3]

[1]*Consiglio Nazionale delle Ricerche- Istituto per la Sintesi Organica e la Fotoreattvità, Italy,*
[2]*Medica spa, Medolla (MO), Italy*
[3]*Industrial and Materials Science, Chalmers University of Technology, Sweden*

Abstract

Much of our tap water comes from rivers, streams, lakes and groundwater. These water resources are increasingly contaminated by discharges of chemicals from industries and urban areas, most of them not fully removed by standard water treatment. Traces of prescription medications, antimicrobial chemicals, pesticides, cosmetics, with suspicious or even proved toxic effects have been found in several EU water bodies, this calling for the development of new efficient, low cost and sustainable purification technologies. In the last years, due to their outstanding adsorption properties, high processability and versatile chemical modification options, graphene-based materials have emerged as the most promising nanomaterials for advanced water treatment technologies.
Here, we report the preparation of new polysulfone/polyethersulfone(PSU/PES)-graphene oxide (GO) composites and their use in filters for removal of selected contaminants from tap water.[1] Stable fixation of GO on commercial hollow fiber membranes (Medisulfoneâ/Versatile PESâ) is achieved by thermal activation under mild conditions.[2] GO enhances the removal of polar contaminants , i.e. of a factor 5 for ofloxacin (antibiotic), with respect to PSU-only and to activated carbon. Working mechanism, regeneration and GO release issues are discussed. The proposed approach is also exploited to revalue and reuse scraps of the industrial production of PS membranes (»1,5 tons/year).[3]

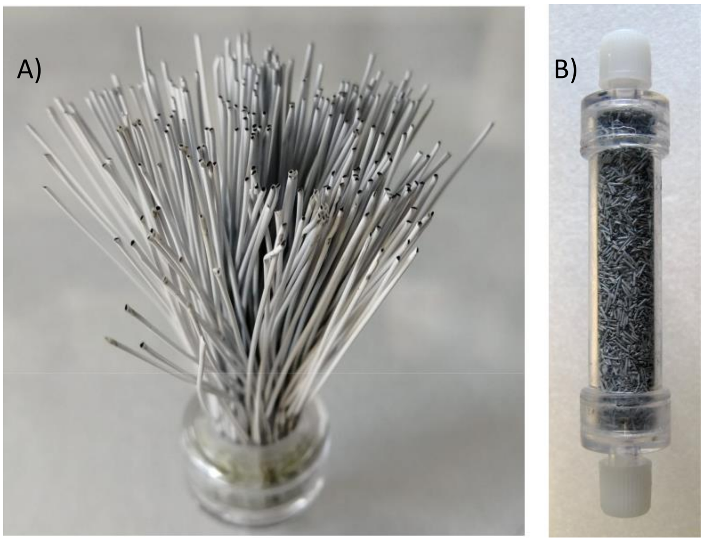

Fig. 1: a) PES-GO hollow fibers, b) PS-GO scraps.

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[2] M. Melucci, V. Palermo, M. Zambianchi, A. Liscio, A. Kovtun, E. Treossi, M.L. Navacchia, L. Bocchi Medica spa-CNR joint Patent application IT 102018000010402 and submitted manuscript.
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Application of GO/rGO membranes for purification and separation

Rakesh Joshi [1]

[1]*School of Materials Science and Engineering, University of New South Wales, Sydney Australia*

Abstract

We have developed a method to make graphene oxide (GO) membranes with proper control in structure and morphology to be ideally used water purification, selective separation and adsorption. In a collaborative project with "Sydney Water" Australia, we have successfully employed our GO membrane to remove Natural Organic Matters (NOMs) from water. Our study shows that GO membranes can reject ~100% of NOM while maintaining high water flux. Furthermore, we have developed a technique that allows controlled reduction of graphene oxide to tune the interlayer spacing and make it suitable for desalination. The reduced graphene oxide (rGO) can have huge potential for desalination applications owing to its appropriate interlayer spacing (0.34–0.37 nm) that enables it to block salt ions as small as Na+ with high precision. However, the fabrication of uniform rGO membranes is a great challenge because of the loss of its polar functional groups during preparation from graphene oxide (GO). We have also utilised GO/rGO membranes for water adsorption (desiccation) application. We conducted experimental study on the adsorption and desorption behaviour of water in GO/rGO membranes as a function of relative pressure. further extend GO membrane's adsorption application we conducted ionic and molecular adsorption behavior of GO membranes. Our results suggest that GO membranes can have potential to be used as ionic/molecular sponge. Our specially tailored GO/rGO membranes also demonstrate excellent molecular sieving behavior when used for gas separation

Acknowledgement

This abstract and the results have been (partially/fully) submitted/presented in other conferences and published in different journals. Everyone contributing to this research is highly acknowledged. Joshi will be presenting on behalf of all the researchers/authors.

Dynamic Spray-Gun Deposition for energy applications and more

Paolo Bondavalli[1], *Gregory Pognon[1], Louiza Hamidouche[1], Lilia Quassym[1], Clemence Rogier[1], Christophe Galindo[1],*

[1]*Thales Research and Techniology, France*

Abstract

This contribution deals with the fabrication of devices based on graphene based nanomaterials using dynamic spray-gun deposition method implemented through roll-to-roll. We used this technique to fabricate sensors, supercapacitors [1], flexible memories [1] and conformable Electro-Magnetic interference Shielding (EMI) layers [2]. In the first case we exploited the nanostructuration of mixtures of graphene and carbon nanotubes (CNTs) to achieve electrodes for supercapacitors. Indeed the MWCNTs are used as sort of spacers to avoid the restacking of graphene. Thanks to that we can exploit the huge surface of graphene to store charges and at the same time we create channels between the layers allowing the rapid charge and discharge of the device. The use of high quality graphene (<5 layers) and MWCNTs, with a diameter of around 20nm, also improve the conductivity for the electrodes and allowed us obtaining an impressive specific power value of around 100kW/Kg using an industrially suitable technique and not only a lab based one [3-4-5-6]. The spray-gun deposition method has been also implemented in the fabrication of GO and CNFs Oxidized based memories. In this case we case spray nanomaterials water based suspensions on a flexible layer previously metallized. The total thickness is around 100nm. After contacting the top with metallic contacts we are able to achieve flexible nonvolatile memories simply applying a bias (<3V). These memories show bipolar behavior and have been cycled 10000 times [2]. They constitute one of the first examples of information storage devices that can be fabricated using a roll-to-roll implementable method. Finally, we have achieved EMS architectures using nanostructuration of graphene, MWCNTs and carbon nanofibers between polymers layers in order to exploit the Maxwell-Wagner-Sillars effect to absorb X-band frequencies [2]. Thanks to this nanostructuration we are able to trap the charges in sort of micro-capacitors created in the layers. This is a real breakthrough considering that usually heavy metal based layers are used and that in this case mm based conformable layers can be obtained opening the route for new kinds of applications. Also in this case the fabrication will be implemented by roll-to-roll fabrication. During the presentation we will show all the details on the first characterization of devices and we will show also perspectives for other potential field of applications.

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Optoelectronics of 2D materials and heterostructures with Γ-point band edges

Vladimir Falko[1], Roman Gorbachev [1], Alberto Morpurgo [2]

[1] National Graphene Institute, University of Manchester [2] Department of Physics, Geneva University

Abstract

We discuss the prospects of 2D materials with Gamma-point band edges for applications in optoelectronics. The family of such materials, developed in WP 'Enabling Research' of Graphene Flagship, includes InSe, GaSe and few-layer films of p-type transition metal dichalcogenides. We show that heterostructures of such materials offer efficient interlayer coupling, promoting layer-indirect optical transitions, which cover a broad range from VIS to IR, depending on the composition of the heterostructure. Also, we show that multi-component stacks of such materials offer a possibility to build IF (including THz) light sources, using intersubband transitions in few-layer films, excited by the interlayer tunneling.

Oxidation of Monolayer WS2 in Ambient is a Photoinduced Process

Michael S. Fuhrer [1,2]

[1]*School of Physics and Astronomy, and*[2] *ARC Centre of Excellence in Future Low-Energy Electronics Technologies (fleet.org.au), Monash 3800 Victoria, Australia*

Abstract

Semiconducting transition-metal dichalcogenides (S-TMDs) have previously been observed to oxidize when left in ambient conditions, however the oxidation mechanism was unclear. Here we show that oxidation of S-TMD WS2 in ambient is a photoinduced process, requiring photon energy greater than the lowest-lying electronic transition in WS2 (trion). Oxidative damage which may be invisible in a conventional optical microscope is readily detected by high-resolution laser scanning confocal microscopy (Fig. 1) at extremely low fluences which do not promote further noticeable oxidation. The threshold irradiances and fluences necessary for oxidation are at least 8 and 4 orders of magnitude lower than previously reported; oxidation occurs after typical Raman or photoluminescence microscopy mapping, or from exposure to room light for periods of days. This finding has significant implications for the storage and processing of S-TMDs in ambient, and may prompt reinterpretation of some past results.

[1] Jimmy C. Kotsakidis, Quianhui Zhang, Amadeo L. Vazquez de Parga, Marc Currie, Kristian Helmerson, D. Kurt Gaskill and Michael S. Fuhrer, *Nano Letters* **19**, 5205-5215 (2019).

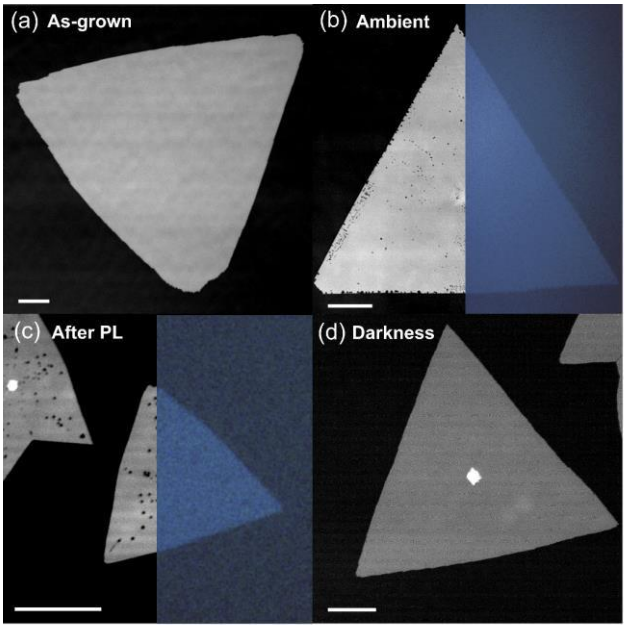

Fig. 1. Laser scanning confocal micrograph (LSCM) of (a) CVD-grown monolayer WS2 exposed to minimal amounts of light before imaging with the LSCM approximately 1 month after growth. (b) WS2 after approximately 19 days in ambient conditions, juxtaposed with an optical image of the same crystal (right half of image). Dark spots seen in the LSCM image are identified as oxidized (likely WOx) regions.

(c) WS2 after routine photoluminescence spectroscopy, juxtaposed with an optical image of the same crystal (right half of image), and (d) WS2 crystals kept in darkness for approximately 10 months with brief exposure to ambient light. Scale bars in all images are 10 μm. From [1].

Graphene and Carbon quantum dot-based composites for energy storage and electrocatalysis

Vincent G. Gomes [1]

[1] *The University of Sydney, School of Chemical and Biomolecular Engineering, Australia*

Abstract

Zero-dimensional (0D) carbon nanomaterials such as carbon (CQDs) and graphene quantum dots (GQDs) have been attracting attention due to their outstanding properties of biocompatibility, nontoxicity, chemical inertness, tunable photoluminescence, low cost and facile surface functionalization [1,2]. Their potential application sectors range from biomedical, drug delivery, environmental, photocatalytic to energy storage. Among these, investigations on energy storage and conversion systems are progressing remarkably rapidly as promising methods are emerging to solve some of the outstanding challenges with energy generation and pollution remediation with minimized cost and environmental footprint.

The rapid electron transfer and high surface areas offered by CQD/GQDs are attractive attributes for a number of electrochemical applications. The presence of rich heteroatoms (oxygen, nitrogen, sulfur, phosphorus, boron, etc.) containing functional groups on 0D carbon nanomaterials present desirable active sites for enhanced electrochemical properties. This presentation is focused on our recent advances in the fabrication of CQD/GQD based composites for electrochemical systems, elucidating their mechanism of action and applying facile synthesis for energy storage (electrochemical capacitors) and electrocatalysis (oxygen reduction reaction, oxygen/hydrogen evolution reactions and electrochemical biosensors). We offer insights on the application and mechanism involved with supercapacitance and electrocatalysis for energy generation using carbon based nanomaterials [3,4]. Figure 1 shows a schematic illustration of 0D carbon nanomaterial applications in energy storage and electrocatalysis.

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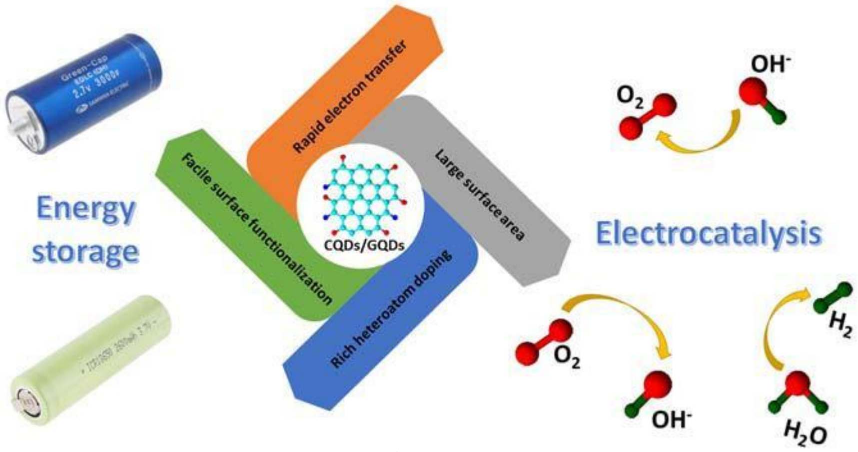

Fig. 1. 0D carbon nanomaterials for energy storage and electrocatalysis

Commercializing graphene sensing solutions

Jaakko Kaidesoja [1]

[1]*Imagine, Australia*

Abstract

Imagine IM has created a sensing platform focusing on graphene's conductivity. Attaching signals processing hardware to the edge of the graphene coated sensing surfaces, different events can be recognized and data can be delivered to customers in a very cost efficient way. Algorithms and further analytics will create valuable information, which helps customer to better manage resources and drive business. Imagine IM is developing solutions for mining, construction, flooring, logistics and automotive industries.

Challenges with Commercialising Graphene

Stephen Hunt [1]

[1]*Graphene Technology Solutions, Australia*

Abstract

Graphene Technology Solutions (GTS), is in partnership with the world reknown University of Adelaide (UA) Graphene faculty. The raison d'être for this collaboration is to commercialise graphene based, environmentally friendly and innovative technologies, which have, up until now, been developed by UA. Specifically, GTS is developing commercial production of various grades of fit for purpose graphene, as well as graphene applications, including protective coatings for anti-corrosive and marine applications, water purification (separation of oil), soil remediation. This presentation will discuss many of the challenges facing a company focussed on commercialising graphene enhanced products. The discussion will include challenges associated with accessing funding including the role of the stock exchange, the need to focus on targeted graphene applications, the importance of industry partners, both technical and commercial, and securing talented people.

Graphene Flagship Validation Service: Providing Confidence in Product Performance

Keith R. Paton [1]

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Abstract

Graphene and related materials offer potential benefits across a wide range of applications and products. This includes automotive, structural composites, thermal management systems, coatings, printed electronics, energy storage, sportswear and equipment. Products in these areas currently exist across a wide range of technology readiness levels (TRL), from proof of concept stage right up to fully launched in the market place. In order for products to be successful it is important for the customers to have confidence in the performance claims or properties that are quoted by the producer. This is as true for the raw materials as for the final products containing these materials.

The absence of accurate measurement protocols and instrumentation for the quality control of produced materials, coupled with the lack of agreed benchmarks and standards have become a serious obstacle to the commercialisation of graphene and related 2D materials. Material and technology validation is costly and complicated, especially in the context of the revolutionising undertaking on the scale of the Graphene Flagship. It requires a professional solution that can enable and accelerate technology development and transfer. As part of the Flagship consortium a Validation Service has been launched to provide the independent measurements needed using validated methods and rigorous quality processes. This service is provided by authorised National Measurement Institutes (NMIs) and facilities renowned for their excellence, independence, integrity and impartiality.

In this talk I will describe the work being led by the National Physical Laboratory (NPL) to develop international standards for graphene and related materials, covering structural and chemical characterisation. These standards will provide an internationally agreed set of protocols for measurement of these materials, accelerating innovation of new products. I will also present case studies from the Graphene Flagship Validation Service, highlighting the importance of independent and validated measurements.

Insights into the exfoliation of graphene and graphene oxide: a quantity control process for achieving desired properties

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Abstract

2D material, graphene (G)/graphene oxide (GO) have attracted tremendous attention due to its exceptional properties. These materials are primarily produced by exfoliation of bulk 3D crystals such as of graphite (Gt), and can be produced in tonnage quantities [1]. However, there is a general lack of methods [1, 2] to quantify the exfoliation process which are fast, label-free, and can be used in-line during synthesising. Our aim is to examine the process of exfoliation of graphite (Gt)/graphite oxide (GtO) particles to the more desirable and useful G/GO material. During the exfoliation process the following types of particles are produced: un-exfoliated graphite/graphite oxide fragments (uGt/uGtO) which absorbs maximum photons and appear as thick dark particles, multilayered partially exfoliated graphite/graphite oxide (pGt/pGtO) particles which shows different degree of transmittance depending on thickness, and the most transmitting single layered G/GO which phase separates into nematic and isotropic liquid crystal. Due to the random nature of the exfoliation process, these particles appear to have large polydispersity in both thickness and lateral size. The polarized light propagating through these 2D material splits into two orthogonal waves with a phase difference in velocities which generates optical retardance, providing vivid and often distinct textures revealing their self-assembled structures. We demonstrate a label free Polarized Optical Microscopy (POM) technique which can provide rich information about the quantities of these different constituents. We then employed a machine learning algorithm to quantify all the particles emerging out of an exfoliation processes.

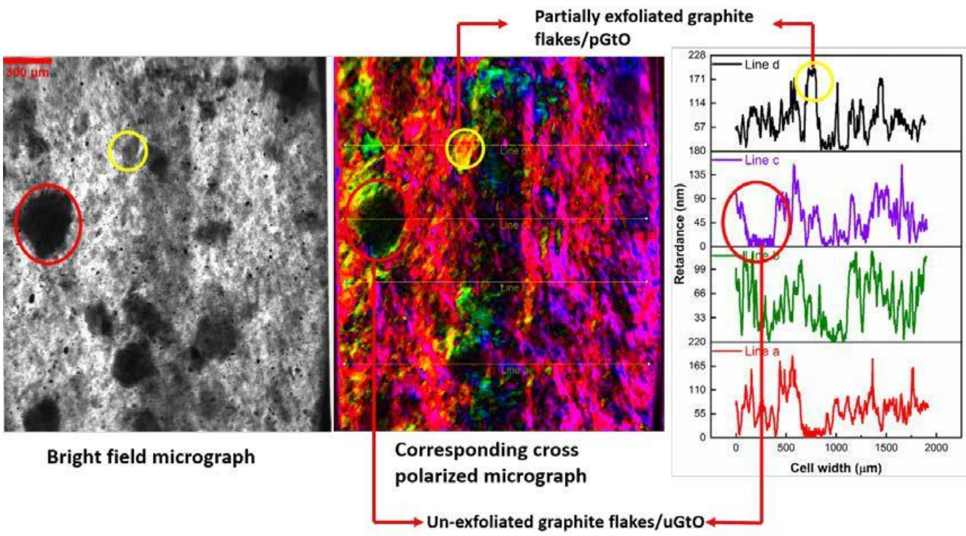

Fig. 1. Optical features of the GtO particles measured in POM. These features have been used to quantify all the particles emerging from the exfoliation process

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Graphene Certification Labs

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Abstract

Manufacturing graphene nanoplatelets (GNPs) is simple and easy to scale. However, the worldwide supply of GNP lacks transparency regarding graphene quality, contamination, functionalization, defects or disorder, all of which can impact the desired properties of graphene incorporation. Without strict quality assurance and control, graphene-containing products will struggle to transition from prototype to production. Similarly, without graphene quality assurance, graphene manufactures will struggle to be incorporated into sophisticated supply chains. The Graphene Certification Labs endeavours to enable graphene-based technologies by offering transparent graphene characterisation to graphene manufactures, product developers or product manufacturers. By analysing graphene at different stages of the supply chain, Graphene Certification Labs is developing open best practices and methodologies with new in-line diagnostics aimed at introduction into manufacturing environments.

Graphene Certification Labs focuses on industrially relevant characterisation that can be applied to the factory floor in bulk and at scale to establish supply chain management for graphene-based products.