# ASX ANNOUNCEMENT

20 January 2021

# December Quarterly Activities Review

Advanced materials company, First Graphene Limited (ASX: FGR, First Graphene or "the Company") is pleased to provide this update on its financial and operational performance for the quarter ended 31 December 2020.

First Graphene has been operating with two key objectives during the quarter under review, being the acceleration of sales to industry and the opening up of new opportunities in energy storage.

- Firstly, it continued to advance the commercialisation of its PureGRAPH® product range during the quarter with commercial sales being made to newGen, planarTECH, Aquatic Leisure Technologies, and a European based multi-national speciality chemicals company. The Company is in detailed discussions with approximately 70 potential customers, globally, at various stages in the designing and trialling of graphene enhanced products. Many of these are expected to evolve into long-term buyers of FGR graphene materials.
- Secondly, the Company has been accelerating its involvement in the development of a number of products and materials which could significantly improve energy storage devices and alternative energy sources. These range from improved solar energy collection technology to advanced supercapacitor materials, alternatives to spherical graphite in anode materials and a new process for the manufacture of green hydrogen.

*Fig. 1: A section of FGR's Commercial Graphene Facility – Henderson WA*

first graphene
The world's leading graphene company



## Novel Supercapacitor Materials

*Achieving capacitance levels 50x greater than activated carbon; 1.0 Farad/$m^2$ as opposed to 0.02 Farad/$m^2$*

At the University of Manchester, a novel route to manufacturing materials which are suitable for pseudocapacitors was identified. The manufacturing process has been progressed by First Graphene, having successfully taken the concept from the laboratory scale to an operational environment in a very short time. This is demonstrated by a scale up from a Technology Readiness Level (TRL) of 3 (experimental proof of concept) to TRL6 (technology demonstrated in relevant environment).

The ideal pseudocapacitor material is a hybrid, consisting of an electrochemically active metal oxide such as manganese (IV) oxide supported on a porous, electrically conductive scaffold such as graphene. This combines the benefits of the high theoretical specific capacitance, wide potential range and high electrochemical activity of manganese (IV) oxide with the good electrical conductivity and versatility of graphene.[1]

First Graphene successfully demonstrated this material can be manufactured at scale via a proprietary electrochemical process. Figure 2 shows high surface area manganese oxide "rosettes" grown onto the surface of a PureGRAPH® platelet. The process is extremely flexible and can be used for deposition of any single or mixed transition metal oxides. This opens other applications, such as electrocatalysts for water-splitting cells used in the production of hydrogen gas.

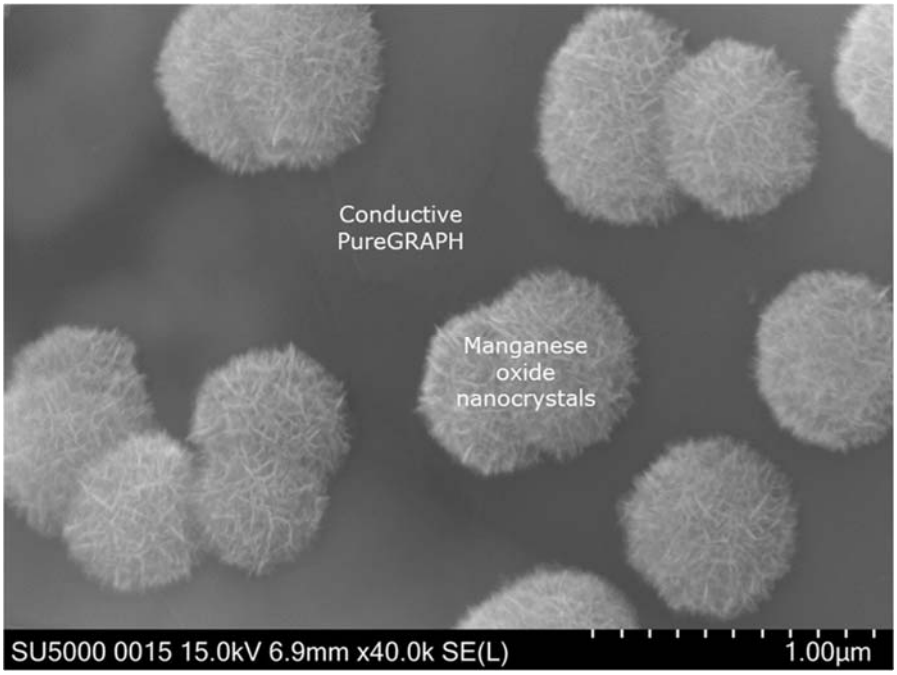


***Fig. 2: Manganese (IV) oxide nanostructures grown directly onto a graphene scaffold***

[1] Wu D, Xie X, Zhang Y, Zhang D, Du W, Zhang X and Wang B (2020) MnO2/Carbon Composites for Supercapacitor: Synthesis and Electrochemical Performance. Front. Mater. 7:2. doi: 10.3389/fmats.2020.00002



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Unlike competitor materials which are often simple mixtures, these materials are unique, having a nano-scale active metal oxide grown directly and intimately onto a conductive carbon scaffold. The Company recognises this unique material requires a novel cell design to optimise performance and continues to work with the University of Manchester on the materials chemistry and with WMG at the University of Warwick with regard to processing the materials into test cells and evaluating the electrochemical performance.

In initial studies, a cell architecture has been devised using the novel metal oxide decorated graphene and standard ancillary materials; binder, separator and electrolyte. The cells have been shown to perform well as supercapacitors easily matching the performance of industry leading activated carbons. Of particular note is the capacitance per unit area of the metal oxide decorated graphene which at 1.0 Farad/$m^2$ is significantly higher than activated carbon at 0.02 Farad/$m^2$. This indicates the manganese dioxide sample exhibits pseudocapacitive behaviour and is not solely reliant on double layer capacitance.

Working closely with the WMG and the University of Manchester, the Company has identified further improvements which will be required in the assembly of supercapacitor cells for these novel materials. The next phase of development will focus upon optimisation of electrolyte and cell lifetime improvements.

## 2D Fluidics

*Improving the efficiency of solar collection cells with the use of proprietary graphene oxide materials*

Work conducted by FGR subsidiary, 2D Fluidics Pty Ltd ("2D Fluidics") with researchers at the Flinders Institute for Nanoscale Science and Technology demonstrated the Green Graphene Oxide (gGO™) produced from the Vortex Fluidic Device (VFD) gives an improvement in the Power Conversion Efficiency (PCE) of organic photovoltaic (OPV) cells. The PCE is a measure of the amount of solar energy which is converted to electrical energy in the OPV cell.

The initial data showed the addition of a relatively small amount of gGO™ as a layer in an OPV cell increased the power conversion efficiency by 8%, taking it into a range which makes it attractive for further research towards the next generation of OPV cells. The efficiency improvement is understood to occur due to the gGO™ decreasing the work function of the active layer.

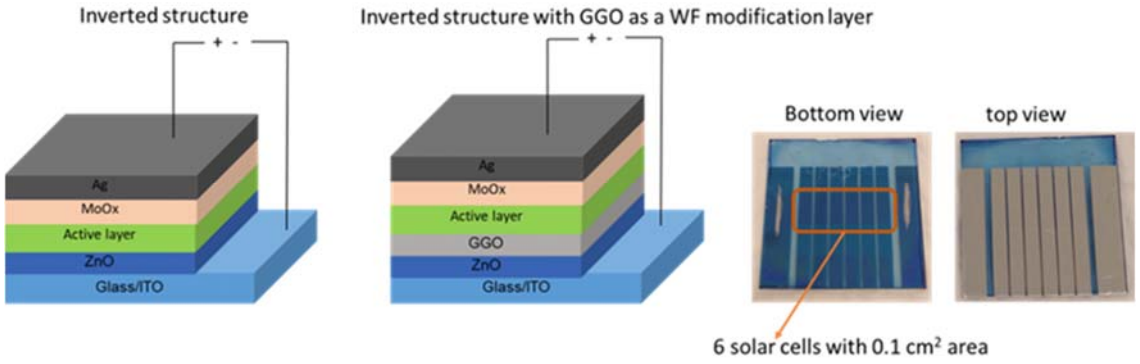


***Fig 3: Schematic of the Organic Photovoltaic Cell design***



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The next step will see the researchers further improve the system, by improving the gGO™ formulation methods as well as attempting to remove the ZnO layer from the cell, to make a flexible organic photovoltaic cell which can be used for a wider range of applications, including wearable sensors.

*Green Graphene Oxide Used to Tune UV Light*

A separate study with researchers at Queensland University has shown Green Graphene Oxide (gGO™) is photoluminescent, with narrow absorption and emissions bands confirming the presence of ordered sp2 domains with a relatively small size. This indicates the VFD can generate pristine graphene, which is separated by functionalised areas, giving it a specific electronic structure, which accounts for the photoluminescence.

The researchers have observed absorption of light at 277 nm with corresponding emissions at 378 nm and 395 nm. This behaviour is not seen in "traditional" graphene oxide produced using Hummer's method. However, it is seen in carbon quantum dots, which has a more regular structure. This demonstrates 2D Fluidics' capability to consistently produce Green Graphene Oxide with controlled surface oxidation levels and a consistent structure.

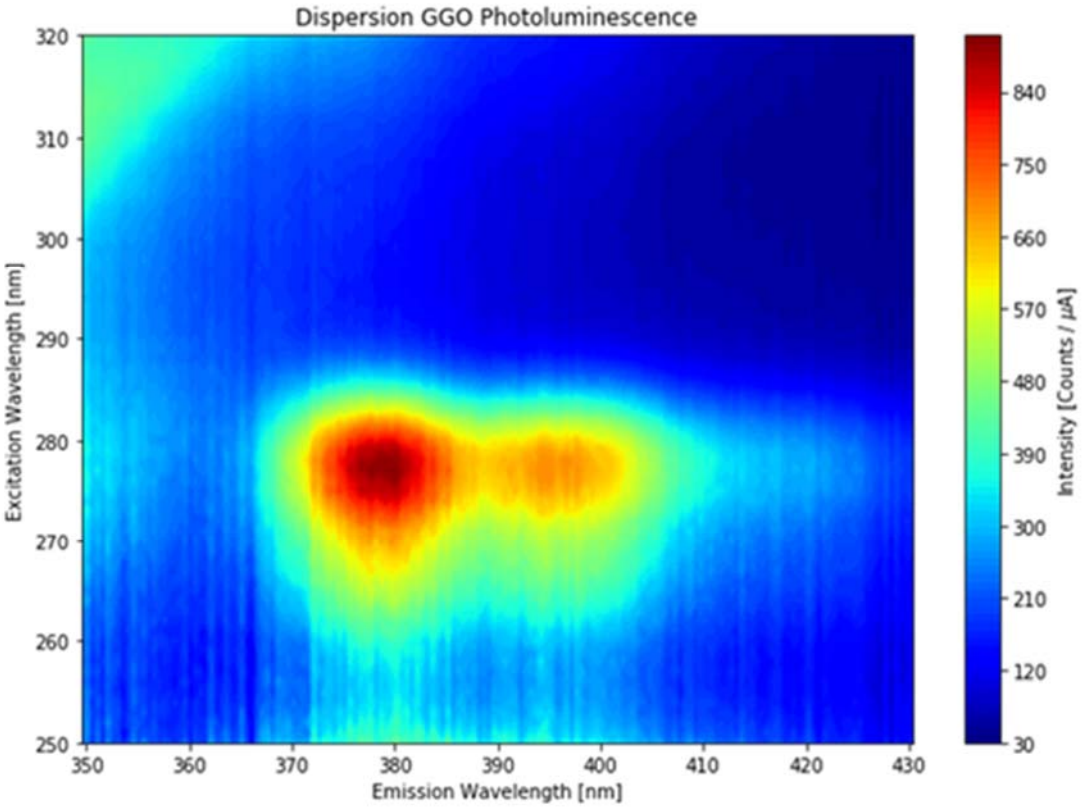


***Fig 4: Green Graphene Oxide – photoluminescence spectrum***



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The preliminary results suggest green graphene oxide may be suitable as a carbon-based additive for applications where more toxic, metal-based quantum dots are currently utilised. This is dependent on further applications testing. However, it could enable gGO™ to be considered for a range of applications such as biosensing, solar cell fabrication and energy storage.

**Scale Up of the Vortex Fluidics Unit**

*Achieving 1,500% increase in VFD throughput with successful scale-up work program*

The combined FGR and 2D Fluidics team worked on the scale up of the VFD and understanding and optimising the process yield.

Results from ongoing Mass Balance Trials conducted at the Graphene Engineering Innovation Centre (GEIC) in Manchester, United Kingdom, in conjunction with Flinders University, indicate a process yield of 28% at present, with identified areas of improvement to fully optimise the process. In conjunction with this work, the 2D Fluidics team at Flinders University have successfully scaled up the original VFD design from 20mm to 50mm giving a throughput improvement of 15 times (1,500%.)

*Large 50 mm Diameter VFD*

For the purpose of establishing scalability, exfoliation experiments carried out in the 20 mm VFD were translated to the 50 mm VFD. The 50 mm VFD includes similar features to the 20 mm VFD; (a) variable rotational speed (500 rpm - 9000 rpm), (b) variable tilt angle (0-90 degrees) and (c) confined mode and continuous flow capabilities (maximum volume capabilities per processing time 30mL compared to 20 mm VFD which can hold a maximum volume of 2mL). Preliminary experiments included (a) efficiency of exfoliation process by varying the rotational speed (2000 rpm, 3000 rpm, 4000 rpm, 6500 rpm). Here, we used 10 mg/mL of graphite ore with a particle size of 500 micron dispersed in 30% aqueous $H_2O_2$

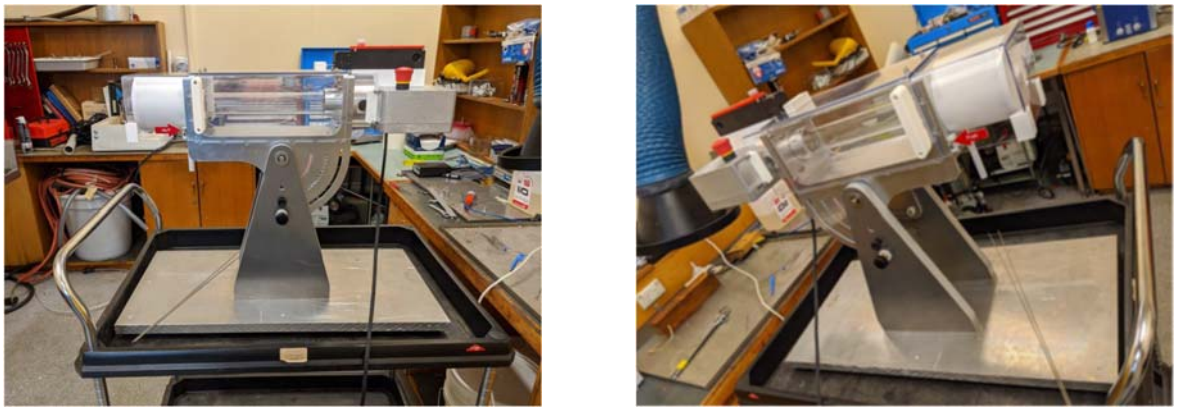

***Fig 5: Large 50mm Vortex Fluidic Device at Flinders University***

Both teams have already identified improvements which can be made to the system to potentially enhance yield and underwrite the further potential scale up of the VFD.



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## 2D Fluidics Energy Storage Materials

*Providing a viable alternative to spheronised graphite in battery anode manufacturing in a market dominated by Chinese companies*

Currently, spherical graphite (SPG) is a crucial ingredient to the efficient operation of lithium-ion batteries (LiB). Spherical graphite is the key component of the anode of a LiB which without, the LiB would not function. Historically SPG has been derived from flake natural graphite.

The global production of spherical graphite is currently dominated by China, which uses the mechanical shaping and hydrofluoric acid purification techniques to produce purified spherical graphite. With the transition of the world to a clean, green energy platform many LiB manufacturers are actively seeking alternative supply options offering better efficiencies. A number of companies around the world are researching alternative graphite products to traditional spherical graphite as a basis for developing graphite mines, but graphene appears to offer something beyond graphite owing to its advanced properties.

FGR is in a unique position to produce a graphene-based spherical product by employing the VFD technology. Research to date has shown the graphene fullerenes could be a suitable replacement for spheroid graphite used in anode manufacturing. The Company's manufacturing process may have the potential to offer improvements in performance, which is a constant issue for battery manufacturers. The fullerenes have potential to enhance both lithium-ion batteries and supercapacitors.

As with all of the other alternatives being worked on by a range of companies, the commerciality and scalability of the production process is dependent upon continuing research and development. Research and development work is being undertaken in the UK in FGR's laboratory at the GEIC, at the University of Manchester and with the University of Warwick.

*Composite Fullerene C60 Graphite Spheres*

Using both the original and the scaled up VFD units, 2D Fluidics has successfully replicated the production of composite C60 / graphene spheres. This work is reported in the publication *"High Yield Continuous-Flow Synthesis of Spheroidal C60@graphene composites as supercapacitors"*[2]. C60 refers to the fullerene form of carbon. It consists of a soccer-ball-shaped cluster of sixty carbon atoms. The graphene-wrapped fullerene composites have a "pom-pom" shape and are known for their unique energy levels and high value of electron affinity energy. They have shown high capacitance when tested in an electrochemical cell by Flinders University.

Importantly, the VFD can produce this material directly from FGR supplied graphite material (D90 500µm). The size of the spheres produced by the 20mm VFD were 1.5–3.0 µm. In the 50mm VFD, using the same raw material production volume was increased and the spheres were ≤ 1 µm.

[2] Raston et al, High-Yield Continuous-Flow Synthesis of Spheroidal C60@Graphene Composites as Supercapacitors, ACS Omega 2019, 4, 19279−19286



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The production of the "pom-pom" shaped graphene-wrapped fullerene spheres has been replicated at FGR's UK laboratory, using similar operating conditions. The controlled manufacture of this new product could give potential performance improvements when compared to the restricted sizing of conventional spherical graphite used as an anode material.

Further experiments in the 50 mm VFD at lower rotational speed will be conducted to demonstrate the ability to control the size of the spheres, test scalability of process and calculate production yield.

FGR is producing sufficient quantities of these novel materials for evaluation in energy storage applications at leading United Kingdom based universities, such as the University of Warwick. Of particular interest is the use of these materials as active materials in supercapacitors and also as lithium-ion battery anodes.

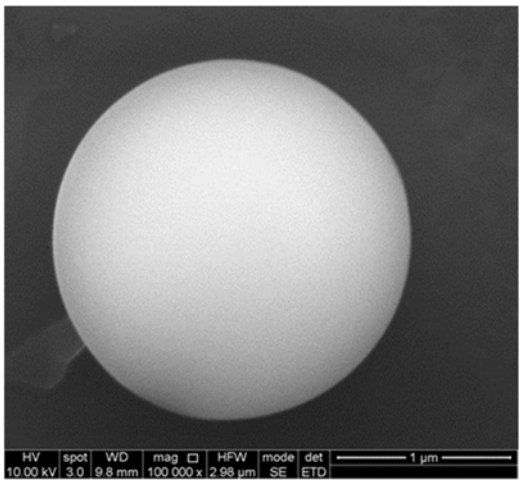


*Fig 6: Graphene Sphere" pom-pom" - 1 µm*

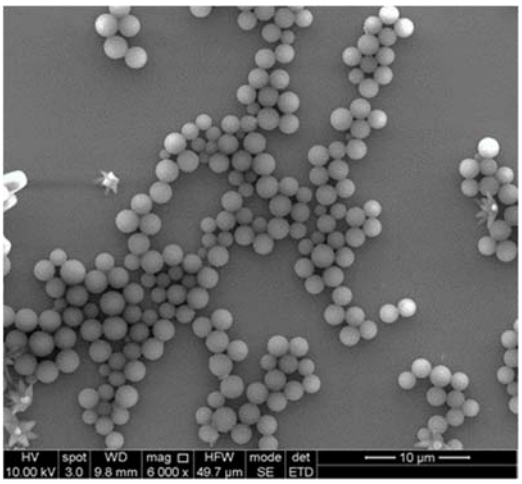


*Fig 7: Spheres from VFD ≤ 1 µm*

## Hydrogen Generation and Graphene-Based Battery Materials

*Researching an alternative green hydrogen manufacturing process to participate in the renewed interest in hydrogen as a power source*

During the December quarter the Company successfully completed initial contracting with InnovateUK and received an initial grant payment of £50,000. Mr. George Danczuk has been appointed as a fully funded Research Technician, to work at the Company's UK labs at the Graphene Engineering Innovation Centre (GEIC) in Manchester.

Dr. Richard Price (Kainos Innovation Ltd), the inventor of the technology, which directly converts low-cost hydrocarbon feedstocks to graphene materials and hydrogen gas, is actively engaged with the First Graphene team. Dr. Price has extensive experience in the chemistry of petroleum products from his many years with Shell Research. In addition, First Graphene will use the Innovate UK funding to acquire additional laboratory facilities to accommodate this project.

The technology transfer from Kainos Innovation to First Graphene will commence early in January 2021 and will initially focus on making proof of concept samples of novel battery-grade materials.



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The appointment of the Research Technician, availability of additional laboratory space and strengthening of the intellectual property portfolio will allow First Graphene to rapidly evaluate the novel technology licenced from Kainos Innovation Limited, focussing on energy storage and hydrogen generation, both of which currently have very strong market pulls.

## Continued Development Work in Concrete

*Validation of significant improvements in concrete compressive and tensile with the addition of PureGRAPH® is leading to test work with concrete industry participants*

During the quarter First Graphene continued development work with PureGRAPH® products in concrete and concrete admixtures. This work was conducted in conjunction with the University of Adelaide, where the Company is a participant in an ARC Hub project.

The manufacture of cement carries a significant $CO_2$ burden which is estimated to be more than 6% of all $CO_2$ emissions from human activity. The industry faces major challenges, notably the pressure to reduce the carbon footprint ($CO_2$ contribution) of cement-based products. The application of new technologies to improve strength and durability of finished concrete products offers a route to improve the efficiency of cement usage and promote lighter, stronger concrete structures which will help reduce the $CO_2$ footprint of the industry.

In a paper published in *RSC Advances*, researchers at the University of Adelaide have validated the mechanism of compressive strength enhancement in concrete materials through the addition of high performing PureGRAPH® concrete additives supplied by First Graphene. In earlier studies, this group demonstrated the compressive strength is increased by 34.3% and tensile strength by 26.9% with the addition of PureGRAPH® pristine graphene at dopant levels of 0.02%w/w in mortars and 0.01%w/w in concrete.

In the publication the researchers, confirmed the statistical significance of earlier studies and further investigated the mechanism for increased strength in cement mortars. Extensive analysis showed the reinforcing mechanism of the graphene additive is based upon denser interfacial zones between the cementitious gel and aggregate particles, leading to more effective stress distribution and inhibition of crack propagation. Pristine graphene platelets with a high aspect ratio and average (volume) lateral size of 56 microns, gave the best performance. These materials are uniquely manufactured by electrochemical exfoliation at First Graphene and supplied as PureGRAPH® concrete additives.

The PureGRAPH® additives were introduced to the cement mortar as an aqueous dispersion within a plasticiser solution which is widely used in the construction industry. All testing was carried out using international standard test methods.

This research confirms the ability of high-quality pristine platelets to increase both the compressive and tensile strength of cementitious composites and concretes. The mechanism of strengthening has been fully validated in the laboratory.



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The researchers conclude *"The results of this study have not only provided a better understanding of incorporating pristine graphene platelets (PRG) into cementitious composites, but they have also shown the great potential for low-cost industrially produced PRG materials for improving the performance of cement-based construction materials."*

Carbon reduction programmes are driving the use of cement alternatives, recycled concretes and the development of lighter/thinner concrete structures and components. High-performing graphene additives could be the solution, be it thinner and lighter concrete materials with similar performance as existing materials or enhanced performance of lower carbon and recycled concretes.

A copy of the research paper is currently available online at: http://rsc.li/34l0Mzv.

## Commercial and Corporate

During the quarter the Company received research and development refunds from the UK for £98,672 (A$179,328) and in Australia for $348,571. 2D Fluidics received a refund of $65,417.

### Leadership Changes

On 9 October the Company announced Managing Director, Craig McGuckin, had given the Board three months' notice of his intention to retire.

Mr McGuckin was a founding director of FGR and had overseen the construction of the world's largest chemical exfoliation graphene manufacturing facility in Henderson, Western Australia.

On 14 December the Company announced that, following an extensive global search, it had appointed Michael Bell as Chief Executive Officer.

With more than 20 years' experience in engineering and business management, Mr Bell has significant international experience driving business growth. He comes to First Graphene from Singapore-based ST Engineering Group where he served as Senior Vice-President. Mr Bell had also held roles as Director for Navman Wireless, a global Telematics company which was acquired by the Danaher Corporation, and as General Manager with Singapore-based shipbuilder Strategic Marine.

### Other Developments

The Company is awaiting the results of examination of the AmourGRAPH™ reclaimer bucket liner which was removed from service in the Pilbara in late November 2020, for evaluation purposes.

The Company will release this information as soon as it is made available by the principal and our customer.



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| Significant December Quarter Announcements | | |
|---|---|---|
| **Date** | **Subject Matter** | **URL Link** |
| 9 October | Founding Managing Director Announces Retirement | https://firstgraphene.net/wp-content/uploads/austocks/fgr/2020_10_09_FGR_3997aa2f4da6343659257a0d116df19a.pdf |
| 14 October | Progress Made with Novel Supercapacitor Materials | https://firstgraphene.net/wp-content/uploads/austocks/fgr/2020_10_14_FGR_6ef2600e57df1a9e2aa6ccffbe3d0f8a.pdf |
| 26 October | Vortex Fluidic Device gGO™ Update | https://firstgraphene.net/wp-content/uploads/austocks/fgr/2020_10_26_FGR_290dba2b52a59d3b8d7af58b820da549.pdf |
| 5 November | New Route to Hydrogen and Graphene-Based Battery Materials Funded by UK Government | https://firstgraphene.net/wp-content/uploads/austocks/fgr/2020_11_05_FGR_8d884d6c1d21bc90442e618652fe386c.pdf |
| 9 December | 2D Fluidics Update on Energy Storage Materials | https://firstgraphene.net/wp-content/uploads/austocks/fgr/2020_12_09_FGR_8e24ee3f26bf1a3731c1a3d12c1b5b65.pdf |
| 14 December | First Graphene Appoints New Chief Executive Officer | https://firstgraphene.net/wp-content/uploads/austocks/fgr/2020_12_14_FGR_9c2b2422cdbc92eb4997c06fd3621971.pdf |



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## About First Graphene Ltd (ASX: FGR)

*First Graphene Ltd. is the leading supplier of high-performing, graphene products. The company has a robust manufacturing platform based upon captive supply of high-purity raw materials and an established 100 tonne/year graphene production capacity. Commercial applications are now being progressed in composites, elastomers, fire retardancy, construction and energy storage.*

*First Graphene Ltd. is publicly listed in Australia (ASX:FGR) and has a primary manufacturing base in Henderson, near Perth, WA. The company is incorporated in the UK as First Graphene (UK) Ltd. and is a Tier 1 partner at the Graphene Engineering and Innovation Centre (GEIC), Manchester, UK.*

## PureGRAPH® Range of Products

***PureGRAPH***® *graphene powders are available in tonnage volumes with lateral platelet sizes of 20µm, 10µm and 5µm. The products are high performing additives, characterised by their high quality and ease of use.*

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## ASX Symbol

**Australia:** FGR
FGROC
**Frankfurt:** FSE:M11
**USA OTC:** FGPHF

*With authority of the board, this announcement has been authorised for release, by Peter R. Youd Director, Chief Financial Officer and Company Secretary.*