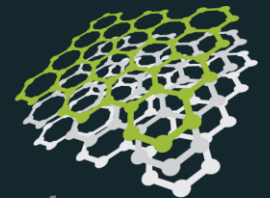




GRAPHENE AUTOMOTIVE 2019  
Detroit 4-5 March 2019

Dr. Andy Goodwin

# DELIVERING ON THE GRAPHENE REVOLUTION



**first** graphene

The world's leading graphene company

# Forward Looking Statements & Disclaimer

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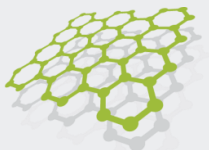
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# Contents



**first** graphene

The world's leading graphene company

- Introduction to First Graphene Ltd.
- Graphene supply and routes to graphene materials
- Importance of both standardisation and product quality
- Emerging applications in the automotive sector – composites, elastomers, fire retardancy and thermal management

First Graphene Ltd. is publicly listed in Australia (ASX:FGR) and has a primary manufacturing base in Henderson, near Perth, WA. The company was recently 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.

# GRAPHENE MARKET

## OVERVIEW

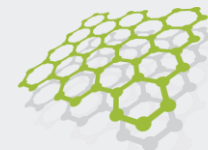


**first** graphene  
The world's leading graphene company

- Graphene, discovered in 2004, is the thinnest, strongest, most flexible, best barrier, most transparent, most conductive (thermal & electrical) material ever isolated.
- Graphene is forecast to create a >\$300million materials market by 2022<sup>1</sup> and enable downstream \$billion markets in transportation, construction, industrial products, energy storage and electronics.
- Graphene powders are typically added to other systems to provide new properties not previously available or enhance the existing properties to new levels.
- To deliver success in the graphene sector, a supplier must have a robust manufacturing platform, competitive cost structure and the capability to drive adoption through downstream investment and partnering<sup>2</sup>.

# FIRST GRAPHENE

.....leading the commercialisation of graphene



**first** graphene

The world's leading graphene company

## Established Supply

- Fully operational plant with capacity of 100 tonne/year.
- Secure raw material supply and robust process.
- REACH registration in place

## Low capital costs

- Low capital cost and short build time.
- Expansion of capacity to support global markets is straightforward.

## Best quality product

- High performing and easy to use products.
- Competitive pricing.

## Commercial traction

- Commercial progress in high volume applications.
- Sales contracting in progress and case studies emerging.

## Strong partnerships

- Tier 1 partner at Graphene Centre (GEIC), Manchester.
- Raw material supplier to University of Manchester programmes.

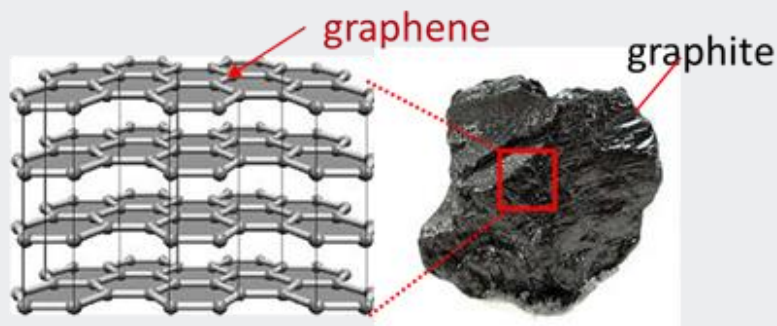
# MANY ROUTES TO GRAPHENE ADDITIVES

..typically by exfoliation of graphite



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The world's leading graphene company



## Graphite Oxidation

- Oxidation/Reduction with strong oxidising agents then reduction (to rGO)

## Graphite exfoliation

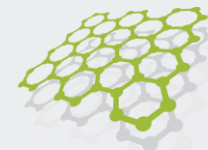
- Mechanical attrition – milling, microfluidisers, homogenisers
- Plasma & heat energy – plasma, DBD, flame and micro-wave
- Ultrasonic exfoliation by cavitation
- Electrochemical exfoliation – ion intercalation by electrical potential

**Material characteristics will depend upon manufacturing method used.**

**Need for high performance analytical testing and quality control....which will enable industry standardisation.**

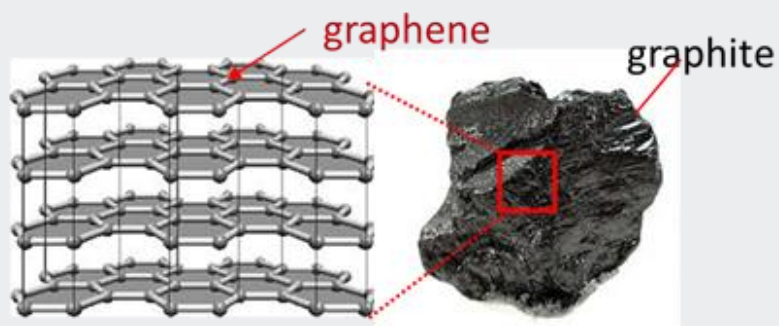
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**Electrochemical exfoliation is the preferred method of First Graphene Ltd.**

**Scalable – Robust – Consistent – yielding high aspect ratio products**

# MANUFACTURING AND SUPPLY PLATFORM

Secure, established, robust and consistent

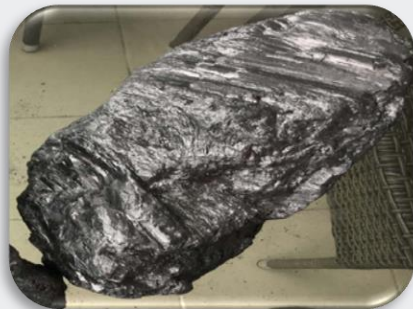


## Secure

- Captive supply of graphite from Sri Lanka.
- 99.5% carbon ore used directly from the ground.
- Right format for exfoliation.
- 5-year stock in-house (at 100tpa).

## Established

- Single step high yield electrochemical exfoliation.
- >90% conversion from graphite ore to PureGRAPH™ products.
- **100 tonne/yr capacity installed today**
- Low capital cost & short build time.



## Robust

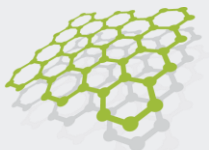
- Scaled finishing and drying steps.
- Proven industrial process tools.
- Controlled product sizes of PureGRAPH™
- Leading edge quality control

## Consistent

- Proven supply and logistics expertise.
- Fully compliant safety data.
- REACH registration in place.
- NICNAS submitted & EPA in progress.





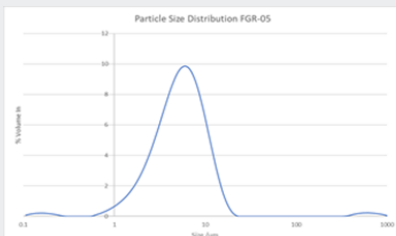


# BEST QUALITY PRODUCTS:

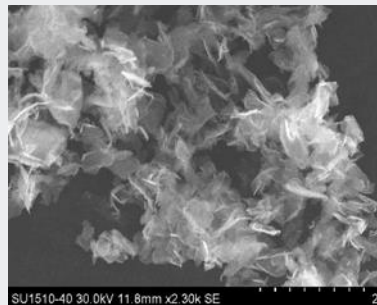
## PureGRAPH™

Consistent, high performing and easy to use

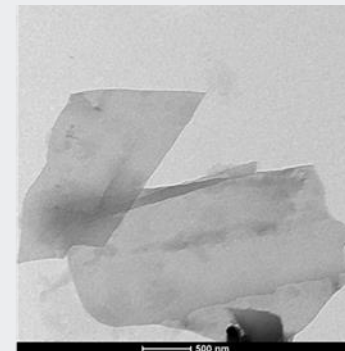
- PureGRAPH™ are graphene nano-platelets with low defects and high  $sp^2$  carbon levels.
- High aspect ratio platelets with high levels of few layer graphene primary particles.
- PureGRAPH™ powders have well controlled particle sizes at  $5\mu\text{m}$ ,  $10\mu\text{m}$  and  $20\mu\text{m}$  for consistent and repeatable performance.
- PureGRAPH™ powders disperse readily and easily in solvents, polymer resins, rubber and water based formulations.
- High purity carbon materials with  $<0.3\%$  total metals and  $<1$  ppm silicon contaminants.



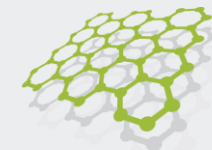
PureGRAPH™ 5 Malvern Mastersizer analysis showing  $D_v(50) = 5\mu\text{m}$  and  $D_v(90) = 11\mu\text{m}$  i.e no large particle tail is present. Laser light scattering is used as a powder size quality control tool. PureGRAPH™ products have very reproducible  $D_v(50)$  and  $D_v(90)$ .



PureGRAPH™ 5 Scanning Electron Microscopy (scale bar =  $20\mu\text{m}$ ): This analysis of dried product powder shows aggregated powders of high aspect ratio graphene platelets. These particles disperse readily in solvent and polymer media.



PureGRAPH™ 5 Transmission electron microscopy (scale bar =  $500\text{nm}$ ): PureGRAPH™ 5 product dispersed in solvent prior to analysis by TEM. The analysis shows few layer graphene (FLG) platelets are present with typical sizes up to  $3\mu\text{m}$ .



# BEST QUALITY PRODUCTS:

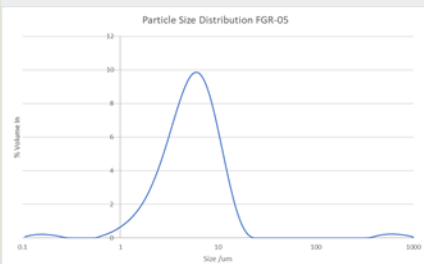
## PureGRAPH™

Bulk Quality – What's in the bag?

First Graphene uses a combination of at-line and laboratory analysis to ensure PureGRAPH™ product quality.

### PureGRAPH™ 5 At-line analysis

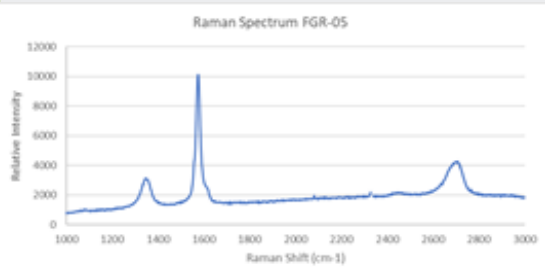
#### Powder Particle size distribution:



Malvern Mastersizer is used to monitor the average particle size<sup>1</sup> of PureGRAPH™ powders.

Ensuring tight control of particle size dispersity in PureGRAPH™ powders.

#### Raman spectroscopy:



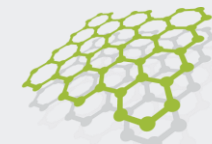
Raman spectroscopy – using a novel bulk powder sampling technique<sup>2</sup>.

Ensuring low defect levels in the sp<sup>2</sup> basal plane and graphene conversion.

### PureGRAPH™ 5 Bulk Properties

Particle size distribution (PSD)	Malvern Mastersizer	Dv(50) = 5.6 µm Dv(90) = 12.5 µm
I <sub>D</sub> /I <sub>G</sub>	Raman	0.17
Graphitic content	Raman	None detected
Total oxygen	Elemental analysis	1.4% w/w
Total metals	ICP	0.3% w/w
Total silicon	ICP	< 1ppm
Tapped Density	ASTM D7481	0.062 gcm <sup>-3</sup>

1. Malvern Mastersizer 3000 – using standard Mie theory  
 2. IRDG 222 Meeting and Poster Session, 20th December 2018, UCL, London



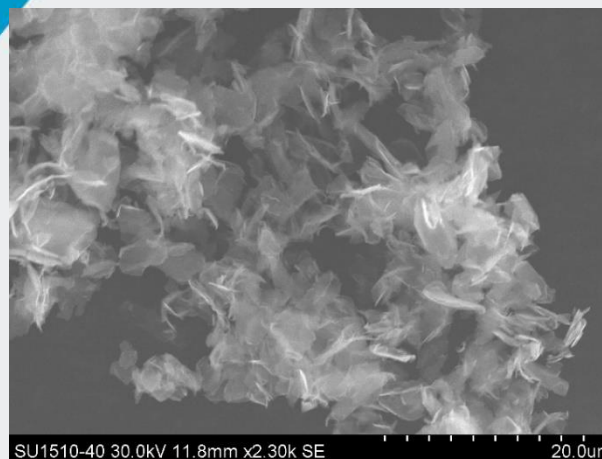
first graphene

The world's leading graphene company

# BEST QUALITY PRODUCTS:

## PureGRAPH™

Graphene Nanoplatelet Quality



### Scanning Electron Microscopy (SEM): PureGRAPH™ 5

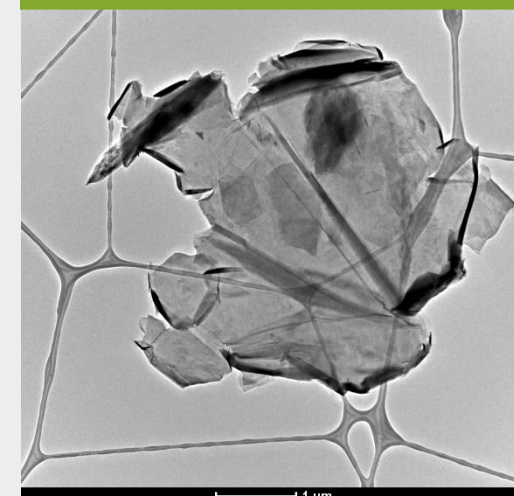
- SEM analysis of PureGRAPH™ powders.
- Direct analysis of secondary powder particles.

**Conclusion:**  
High aspect ratio GNP particles with little agglomeration. Sizes correlate well with PSD data.

### Transmission Electron Microscopy (TEM): PureGRAPH™ 5

- Analysis to NPL best practice guide<sup>3</sup> which isolates primary particles.
- TEM shows high content of Few Layer Graphene (FLG) platelets.
- As expected there is a range of platelet diameters.
- Example shown is a 4 um FLG showing smaller < 1 um FLGs

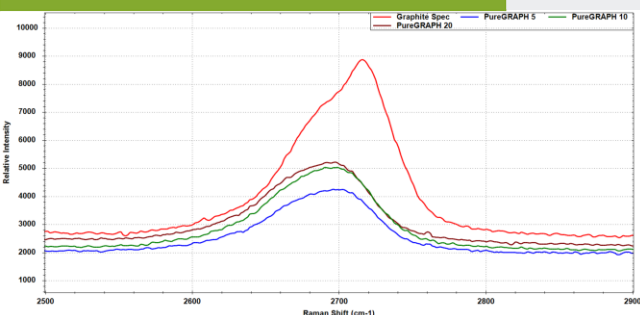
**Conclusion:**  
Product contains high levels of FLGs.



### Raman 2D band analysis:

- 2D band provides information on number of sp<sup>2</sup> layers.
- Published literature<sup>1</sup> states that absence of graphitic band indicates < ca. 5 carbon layer.
- Bulk powder sampling method used<sup>2</sup>.

**Conclusion:**  
Average GNP thickness is < 10 layers



1. Ferrari, A. C. et al. Raman spectrum of graphene and graphene layers. Phys. Rev. Lett. 97, 187401, (2006).

2. IRDG 222 Meeting and Poster Session, 20th December 2018, UCL, London

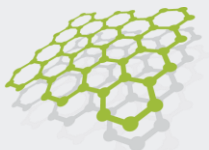
3. National Physical Laboratory Good Practice Guide 145



## Benefits of PureGRAPH™ Additives

# INDUSTRIAL COMPOSITES

Light-weighting and water resistance



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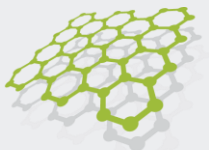
Benefits of using **PureGRAPH™**  
graphene additive in composites:

- Increased strength (> 30%)
- Light-weighting (> 25%)
- Increased water resistance
- Increased electrical & thermal conductivity
- Simplified manufacture
- Reduced cost



# ELASTOMERS

Wear Liners – Mining and mineral handling Industries

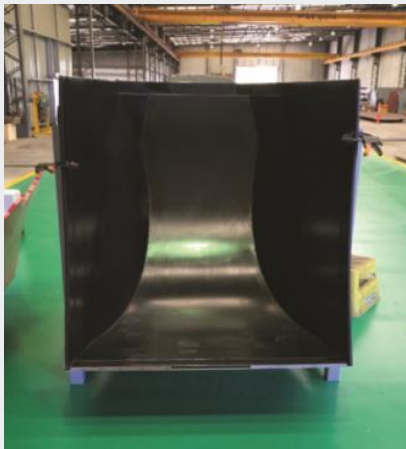


first graphene

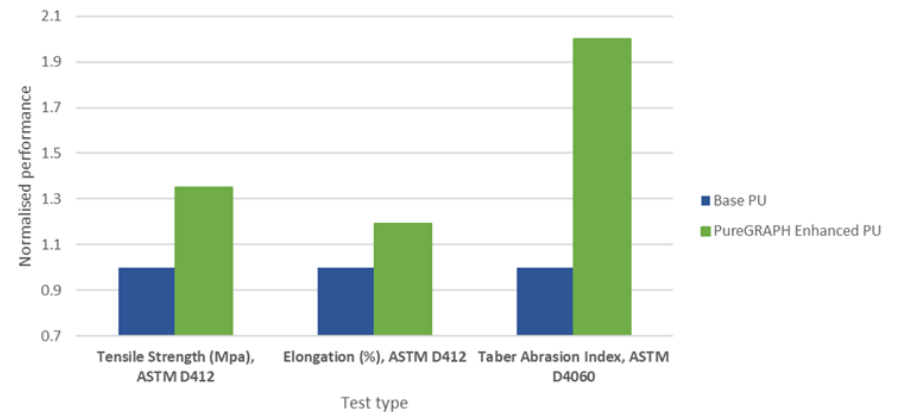
The world's leading graphene company

Benefits of using **PureGRAPH™** graphene additive:

- Easily dispersed
- Increased strength
- Supreme abrasion resistance
- Increased electrical & thermal conductivity

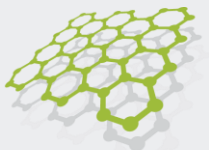


Performance Increase of PureGRAPH(TM) enhanced Polyurethane Elastomers vs. Base Material



# FIRE RETARDANCY

FireStop™ Paint/Coating



first graphene

The world's leading graphene company

Benefits of using **PureGRAPH™** graphene additive:

- Self-extinguishing
- Prolongs structural integrity
- Suppression of toxic and flammable volatiles
- Environmentally friendly compared with existing FR solutions



**FireStop™ timber coating**  
**UL94=V0 and LOI = >40 on balsa.**

# CONSTRUCTION

Stronger, lighter, greener concrete



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The world's leading graphene company

Benefits of using **PureGRAPH™** graphene additive:

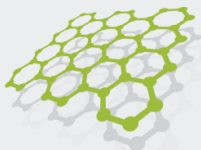
- Stronger and lighter concrete structures<sup>1</sup>
  - +34% in compressive strength
  - +27% in tensile strength
- Reduction in material usage and carbon footprint caused by cement-based products
- Reduced water permeability for increased longevity of concrete structures





# THERMAL MANAGEMENT

With Flexegraph



first graphene

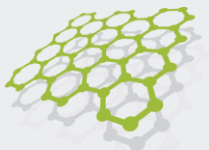
The world's leading graphene company

Benefits of using **PureGRAPH™** graphene additives:

- Reduced charging times
- Extended battery life
- Thermal runaway prevention
- Enhanced charging in cold climates



# FIRST GRAPHENE SUMMARY



**first** graphene

The world's leading graphene company

**First Graphene offers customers a secure and consistent supply of high performing PureGRAPH™ additives.**

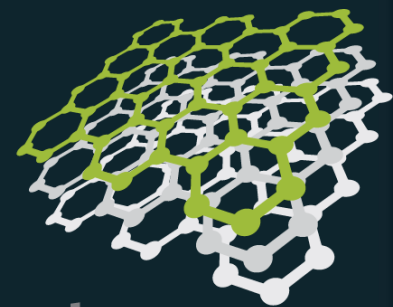
**PureGRAPH™ products are low-defect, high aspect ratio graphene nanoplatelets with high levels of Few Layer Graphenes.**

**PureGRAPH™ have proven performance in industrial composites, elastomers, fire retardancy and concrete.**

**Supply chain is established at 100 tonne/year and PureGRAPH™ product registration is in place in Europe and in progress in Australia and USA.**

**Please stop by and visit our exhibit if you have further questions.**

**PureGRAPH™**  
**It's all about quality**



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