GRAPHENE PRODUCTION IN 2020

PRESCOUTER



What is the current status of graphene production?

The gold rush for graphene started when the 2010 Nobel Prize in Physics was awarded to Andre Geim and Konstantin Novoselov, for their 2004 discovery of a method to produce near-monolayers of graphene, today known as the "Cellophane-tape" or the "Mechanical exfoliation method". The method sparked high interest as it enabled scientists to conduct a new generation of research on graphene. Graphene was marked as a "wonder material", being incredibly strong, light and flexible. It was expected that graphene molecular film would revolutionize research materials, electronic and communications equipment, and a wide-range of industrial activities.

In 2015, all suppliers of graphene were small, privately-held companies. Has anything changed since then? What is the status of graphene production today?



In **2019**, the global graphene \$78.7M market size was estimated at

In **2027** is expected to reach

\$**1.08**B

Major applications of graphene materials are in areas such as: electronics, composites, energy, coatings and catalysts.

In order to understand the current status of graphene production, PreScouter identified **18 companies** that produce or are very close to commercially producing graphene and graphene-based products. PreScouter collected and analyzed the information from the public domain of the companies and their products and processes.



PreScouter identified 8 companies

The impression is that graphene is entering commercially available products more and more. Information that supports this are: news on launching of commercial products; moving from pilot scale production to commercial scale production; and planned production scale-ups of commercially available processes. Some examples to highlight:

Haydale supplies graphene to Briggs Automotive Company that has launched the first production car with fully incorporated graphene-enhanced carbon fibre in every body panel (*July 2019*)

XG Sciences' graphene can be found in Grays' field hockey sticks with the aim to elevate player performance through lightweight, improved ball control and power delivery (January 2020)

Applied Graphene Materials launched 4 graphene-enhanced products (primer, anti-corrosion primer, liquid coating roofing system, anti-corrosion coating for harsh environments) in the coatings sector (March 2020)

SUMMARY OF THE GRAPHENE PRODUCERS COVERED IN THIS REPORT



Companies located in few main areas:

Canada, Australia, and UK (each with 4 companies)

Most of them still small sized companies and founded in the period of graphene "gold rush" (2010-2015)

 Inickness 5-15 atomic Iayers (1-10 nanometers); average particle sizes 0.3 - 150 microns additive; silicon anode composite for LiB anodes, membranes, textiles, adsorber, asphalt and others 	 14 out of 18 provide graphene powders; average thickness 5-15 atomic layers (1-10 nanometers); average particle sizes 0.3 - 150 microns 	 9 out of 18 provide graphene added products such as composites and inks (most common); other products: thermal management grease; cement additive; silicon anode composite for LiB anodes, membranes, textiles, adsorber, asphalt and others 	2 out of 18 provide technology and know how	5 out of 18 provide graphene oxide
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Exfoliation is the **most common** production method, followed by chemical vapor deposition

Total production capacity **>755** tons/year

DISTRIBUTION OF GRAPHENE PRODUCERS

Name



PRESCOUTER 5

PRODUCT ANALYSIS

Company	Product offering					
	Graphene materials (su	h as powders, suspensions and dispersions)		Value added products containing graphene	Technology and know-how	Graphene oxide
NanoXplore	Powders	Average thickness of 6-10 layers	Average flake size - 0.5-1.0 microns; average agglomerate size - 13 microns	Composites (polyurethane, PP, PE, nylon, rubber and epoxy)		
XG Sciences Inc	Powders	Unknown	Platelets average particle size - 5- 25 microns	Composites (HDPE, PET,PP, polyurethane); thermal management grease; cement additive; silicon anode composite for LiB anodes; inks	X	
Versarien PLC	Powders	Unknown	Average flake sizes of 10 and 26.5 microns	Composites and inks	Х	Х
Elcora Advanced Materials	Powders/ suspension	Average thickness of 2-4 layers (1-5 nanometers)	Average sheet size - < 5 microns	/		
Haydale Graphene Industries plc	/	/	/	Graphene-based material solutions		
Thomas Swan	Powders, dispersion, paste	Unknown	Platelets smaller than 9 microns	Masterbatches		
First Graphene	Powders	Unknown	Platelets average size 5, 10, and 20 microns	/		
Applied Graphene Materials	Powders/water and polymer dispersions	Average thickness of 5-15 atomic layers (1-10 nanometers)	Platelets average size 1-15 microns; dispersions 5 -150 icrons	/		

PRODUCT ANALYSIS

Company	Product offering	roduct offering				
	Graphene materials (su	ch as powders, suspen	sions and dispersions)	Value added products containing graphene	Technology and know-how	Graphene oxide
Talga	Powders	Unknown	Platelets and flakes	/		Х
Grafoid	Powders	Unknown	Unknown	Inks		
G6 Materials	Powders, solutions, foams, aerogel, chemical vapor deposition	Average thickness from a few nanometers to tens of nanometers	Average flake size - 0.3-25 microns	/		Х
Graphenea	Films	/	/	/		Х
Directa Plus	Powders	Unknown	Platelets	Composites, membranes, textiles, adsorber, asphalt		
Graphene NanoChem	/	/	/	Composites, inks, nanofluids		
ZEN Graphene Solutions	Powders	Unknown	Unknown	/		Х
Archer Exploration Ltd.	In development					
Comet Resources	In development					
2D Carbon Graphene Material	/	/	/	Graphene pressure and touch sensors, heating films, membranes and other graphene products		

PRODUCTION CAPACITY ANALYSIS

Company	Production method	Capacity, t/year
NanoXplore	Liquid exfoliation	25; currently developing a fully-automated,10,000 tonnes/annum production facility
XG Sciences Inc	Chemical and mechanical exfoliation	300-600
Versarien PLC	Not specified	Unknown
Elcora Advanced Materials	Exfoliation	Unknown
Haydale Graphene Industries plc	Not specified	Unknown
Thomas Swan	Not specified	20 - 40
First Graphene	Electrochemical exfoliation	100
Applied Graphene Materials	Solution-based decomposition of metal alkoxide	Have a commercial-scale production facility
Talga	Electrochemical exfoliation	Unknown
Grafoid	Exfoliation	Unknown
G6 Materials	Carbon vapor deposition; chemical exfoliation	Unknown
Graphenea	Chemical vapor deposition	Unknown
Directa Plus	Thermal expansion followed by exfoliation	30
Graphene NanoChem	Chemical synthesis	Unknown
ZEN Graphene Solutions	Exfoliation (mechanical; chemical; electrochemical)	Unknown
Archer Exploration Ltd.	Electronic exfoliation	Unknown
Comet Resources	Electronic exfoliation	Unknown
2D Carbon Graphene Material	Chemical vapor deposition	200,000 m² per annum



As of May 2020. [Source]

*data not available



COMPANY PROFILES



Graphene Production in 2020

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NanoXplore	<u>12</u>
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Elcora Advanced Materials	<u>28</u>
Haydale Graphene	<u>31</u>
Thomas Swan	<u>35</u>
First Graphene	<u>39</u>
Applied Graphene Materials	<u>42</u>
Talga Resources	<u>50</u>
Grafoid	<u>54</u>
G6 Materials	<u>59</u>
Graphenea	<u>70</u>
Directa Plus	<u>78</u>
Graphene NanoChem	<u>83</u>
Zen Graphene Solutions	<u>85</u>
Archer Exploration	<u>89</u>
Comet Resources	<u>91</u>
2D Graphene Material	<u>94</u>



Founded: 2011 Website: https://www.nanoxplore.ca Headquarters: Montréal, Canada Contact: info@nanoxplore.ca



Overview

NanoXplore is a Canadian large-scale manufacturer and supplier of high-quality graphene powder and developer of graphene-enhanced plastics and composite products. The company aims to replace current carbon-based additives, such as carbon black, within the thermoset and thermoplastic market by offering standardized graphene-based products and solutions in powder and masterbatch formats. NanoXplore, employs around 400 people and operates 8 production plants in Canada and Switzerland with more than US\$ 70 million in annual run-rate sales.

The company's composite group consists of:

- Cebo Injections SA: Acquired in 2017; specializes in precision injection moulding
- RMC/Sigma Industries: Acquired in 2018; manufacturer of moulded plastics and composite parts and assemblies
- Faroex/Sigma Industries: Acquired in 2018; specializes in manufacturing large composite products through pultrusion, resin infusion, reaction injection molding, and structural injection molding processes

Aetrics	Product type:	Powder	Production capacity:	25 tonnes/year
Key N	Production methods:	Liquid exfoliation	Applications:	Thermoplastic forming; plastic pipes; agricultural films; transportation; (electronic) packaging; wires and cables





Most recently, on April 3rd, 2020, the company announced the completion of the placement for total gross proceeds of US\$ 25,000,040. The company intends to use the net proceeds to further research initiatives, particularly related to the use of graphene in lithium ion (Li-ion) batteries, US expansion, debt repayment, working capital and general corporate purposes.

Some of the investors include:

- Investissement Québec
- Martinrea International Inc.
- Business Development Bank of Canada (BDC)
- NanoXplore's management.





Graphene Powders	Product	Description	Average flake size	Average agglomerate size	Applications
	GrapheneBlac kTM 0X	Few-layer graphene platelets with the average thickness of 6-10 layers	0.5-1.0 micrometers	13 micrometers	For use in thermoplastics, rubbers, and, especially, in thermosets, inks, paints and coatings
	GrapheneBlac kTM 3X	Few-layer graphene platelets with the average thickness of 6-10 layers	average flake size - 1-2 micrometers	38 micrometers	For use in thermoplastics, thermosets, inks, coatings, and rubbers

	Product description	Applications	
	Thermoplastic polyurethane-graphene composites	Dashboards soft skins	
	Polypropylene-graphene composites	Bumpers	
selles	Polyethylene-graphene composites	Fuel systems	
sodu	Rubber-graphene composites	Tires	
00	Nylon-graphene composites	Under the hood parts	
	Epoxy-graphene conductive gel coats	Class A paints	
	Graphene enhanced polyethylene pipes	Oil & gas industry, drainage, irrigation, industrial processing, conduits	





Enhanced production capacity (17 Jan 2020):

The company is currently developing a fully-automated,10,000 tonnes/annum production facility in Ville St-Laurent, Quebec, Canada (first phase of production at 4,000 tonnes/annum expected in Q1 2020; second, adding the remaining 6,000 tonnes/annum - in Q1 2021).

References:

- 1. <u>https://www.nanoxplore.ca/wp-content/uploads/2019/12/NanoXplore-Corporate-Presentation-Website-October-3-2019-3.</u> pdf
- 2. https://www.nanoxplore.ca/wp-content/uploads/2019/09/Nanoxplore-GrapheneBlack-0x-Datasheet-03122019.pdf
- 3. https://www.nanoxplore.ca/wp-content/uploads/2019/09/Nanoxplore-GrapheneBlack-3x-Datasheet_03122019.pdf
- 4. https://www.nanoxplore.ca/wp-content/uploads/2020/04/GRAPHENE-in-Canada-English-_Feb2020_V2.pdf
- 5. https://www.nanoxplore.ca/update-on-commercial-graphene-facility/
- 6. <u>https://www.nanoxplore.ca/nanoxplore-announces-closing-of-25-million-bought-deal-private-placement-and-corporate-upd ate/</u>



Founded: 2006 Website: <u>https://xgsciences.com</u> Headquarters: Lansing, MI 48911, USA Contact: info@xgsciences.com



Overview

XG Sciences Inc. is a manufacturer of graphene and developer of graphene-enhanced products. The company owns 2 ISO 9001-2015 certified manufacturing sites in the USA wherein 2 proprietary production processes are employed to obtain graphene nanoplatelets from graphite. XG Sciences Inc., serves over 1,000 clients across 47 countries. In 2019, the company generated nearly US\$1.37M in sales revenue. The company size is 51-200 employees. XGSciences offers two main product groups: bulk powders, slurries and cakes & specialty products.

y Metrics	Product type:	Powder	Production capacity:	 Chemical exfoliation - 50 to 100 metric tons/year Mechanical exfoliation - 250 to 500 metric tons/year
Ke	Production methods:	Chemical and mechanical exfoliation	Applications:	Automotive; sporting goods; packaging; industrial





Since inception and through December 31, 2019, XGSciences has raised approximately \$50 million of capital through the issuance of equity and equity-linked securities, \$4 million through licensing fees and \$10 million through the issuance of certain lease and senior debt obligations. Some of the most prominent investors include DOW Chemicals and Samsung ventures.

Period	Investor	Amount (US\$ million)
2006-09	Angel Groups, HNW Individuals	2.0
2010	Hanwha Chemical	3.0
2010	ASC-XGS, LLC	1.6
2011	POSCO	4.0
2011	Cabot Corp	4.0 (licence agreement)
2014	Samsung Ventures	3.0
2014	POSCO	1.2 (pre-emptive rights)
2014-15	Aspen/XGS II	10 + 1.0 (lease)
2015	Series B	4.3
2016	Dow Chemical	10 (senior credit facility)
2016-19	Public Offering	21 (including 3 from Soulbrain)





Customer applications



Customer applications: XGSciences materials used in customer products

Product Overview - Bulk Powders, Slurries and Cakes

This product type is called xGnP® of 4 grades (H, M, R and C). These are stacks of graphene sheets - platelets - with a similar average thickness and surface area. The main differences between each grade are listed in the table.

Product	Typical surface area	Average thickness	Average particle diameter
xGnP® GRADE R	30-60 m²/g	N/A	7, 10 or 25 microns (larger particles also available)
xGnP® GRADE H	50-80 m²/g	15 nm	5, 15 or 25 microns (larger particles also available)
xGnP® GRADE M	120-150 m²/g	6-8 nm	5, 15 or 25 microns (larger particles also available)
xGnP® GRADE C	300 to 750 m²/g	Few-nanometers	Less than 2 microns

Product Overview - Specialty Products



Product	Description	Main characteristics	Applications
XGHDPETM	Graphene-enhanced high-density polyethylene composite	 30% higher tensile strength at break 15 % higher flexural strength 25% higher flexural modulus 20% higher Izod impact strength 	Bottle and film production
XGPETTM	Polyethylene terephthalate composite	 30% higher tensile modulus, > 35% higher flexural modulus > 120% higher Izod impact strength 5% longer shelf life > 40% decrease in processing energy 	Bottles, films, construction, and consumer goods
XGPPTM:	Graphene-enhanced polypropylene masterbatch	 > 80% higher tensile modulus, > 35% higher flexural strength > 70% higher flexural modulus > 180% higher Izod impact strength up to 50% decrease in processing energy 	Wide range of applications (e.g. car bumpers, helmets, hoses, mats, films)
XGPUTM	Graphene-enhanced polyurethane foam	 > 15% improved sound absorption coefficient 20 % higher compression strength 30% higher heat deflection temperature 	Automotive, sporting goods, marine, footwear, construction and sound barrier applications
XGCONCRETETM	Specially formulated graphene-enhanced concrete additive	 reduces cement cracking and degradation effect 	Construction
XG TIM®	Graphene-based compound	 improved thermal properties viscosity: 120 Pa.s thermal conductivity:1.6 W/m.K 	Electronics, automotive electrical components and lighting industries

Product Overview - Specialty Products



Product	Description	Main characteristics	Applications
XG SiG®	Graphene-stabilized silicon anode material for LIB anodes	 reversible capacity: 500-2000 mAh/g 1st cycle efficiency: 85-90% charge/discharge rate: to 5C recommended binders: polyacrylic acid, carboxyl methyl cellulose, styrene-butadiene rubber 	Drone aircraft, portable electronics and other high density energy storage applications
XG3DPTM	Graphene-based formulations	 improved energy efficiency and polymer material performance 	3D printing
XG Leaf®	Thin, flexible and lightweight graphene sheet product family	 sheet thickness: 30-240 microns sheet size: 11.5 x 23.5 inches tensile strength: 10 MPa in-plane thermal conductivity: above 550 W/m.K in-plane electrical conductivity: 3700 S/m max operating temperature: 450oC; RoHS compliant 	Thermal management, EMI shielding and electrodes
XGInk	Electrically conductive, graphene-based, well-adhering ink	 SG-201: Thinner: isopropyl alcohol Solids: 15% viscosity: 0.4 Pa.s Sheet resistivity: 25-35 ohm/sq.mil Drying time at 70oC: 5-10 min WG-201: Thinner: water Solids: 19% Viscosity: 0.9 Pa.s Sheet resistivity: less than 10 ohm/sq.mil Drying time at 70oC: 5-10 min 	Flexible print application methods



Graphene nanoplatelets for field hockey sticks

Jan. 20, 2020: XG Sciences announced the innovative use of its graphene in Grays' field hockey sticks (seen in adjacent image) to elevate player performance through lightweight, improved ball control and power delivery.

Graphene supply to the North American tire markets

Dec. 9, 2019: XG Sciences announced entering into commercialization and license agreements with Perpetuus Advanced Materials, the producer of dispersible, surface-modified graphene. These agreements will enable a closer collaboration between the companies to develop and supply functionalized graphene for elastomers in tire and related applications in the North American as well as global markets.

Graphene for 3D printed products and production

Oct. 28, 2019: XG Sciences announced the joint development agreement with Terrafilum®, an eco-friendly, filament producer for the 3D printing industry, to develop, produce and market 3D printing filaments and coatings using graphene-based materials. The companies will utilise graphene-enhanced filaments to improve product strength and create lighter parts in less time.

References:

- 1. <u>https://xgsciences.com/wp-content/uploads/2020/01/XGSciences_Grays-PressRel-FINAL3.pdf</u>
- 2. https://xgsciences.com/wp-content/uploads/2019/12/XGSciences_PCT-PressRel-FINAL.pdf
- 3. https://xgsciences.com/wp-content/uploads/2019/10/XGSciences_Terrafilum-PressRel-FINAL3.pdf









Founded: 2010 Website: http://www.versarien.com Headquarters: Gloucestershire, UK Contact: info@versarien.com



Overview

Versarien PLC is a knowledge-driven advanced materials group that utilizes proprietary technology to create new engineering solutions. The company boasts a high number of (inter)national collaborations, and reported more than US\$ 11 million in revenue (approximated) in 2019. Company size is 51-200 employees. The group is comprised of:

- 2-DTech Limited (a supplier of graphene products)
- Cambridge Graphene Limited (a supplier of graphene inks and developer of graphene/2D materials technology and applications)
- Gnanomat S.L. (a developer of environmentally-friendly graphene production process)
- Versarien Graphene Inc (USA-based sales business of graphene products)
- AAC Cyroma Limited (a producer of graphene-enhanced plastic products)
- Total Carbide Limited (a European manufacturer of sintered tungsten carbide primarily for harsh environments)
- Versarien Technologies Limited (a developer of additives for microporous metals with improved thermal performance)

letrics	Product type:	Powder	Production capacity:	Not specified
Key M	Production methods:	Not specified	Applications:	Inks and coatings; electronics; lightweight solutions; wearable technology





Significant shareholders

Versarien raised more than US\$ 6 million via PrimaryBid in 2018.

PrimaryBid is an online platform that enables retail investors to gain access to discounted equity offerings of publicly listed companies

Shareholder	% held
Hargreaves Lansdown	25.67
Interactive Investor Trading Limited	10.20
Halifax Share Dealing	6.99
A J Bell Securities	4.77
Barclays Stockbrokers Limited	4.61
Equiniti Shareview	3.89
Jarvis Investment Management Limited	3.72





	Product	Producer	Main characteristics	Applications
Powders	NaneneTM	2-DTech Limited	High purity, low defect, few-layer graphene powder with graphene flake sizes up to 10 micrometers	Composite, energy, biomedical, membrane, coating, sensor, and electronic applications
Graphene	GNP-HP	2-DTech Limited	High quality, few-layer graphene powder with with graphene flake sizes up to 26.5 micrometers	Enhancing mechanical properties in composite materials
Reduced) Graphene Oxide Powders	GO Versarien	2-DTech Limited	A few-layer, oxygen-rich (about 35 %) graphene powder with with graphene flake sizes up to 4 micrometers	Lightweight composites, concrete, metal-matrix composites, corrosion protection, improved barrier properties, permeation and mechanical performance
	RGO Versarien	2-DTech Limited	A multi-layer, oxygen-containing (about 12 %) graphene powder with graphene flake sizes up to 20 micrometers	Li-ion batteries and fuel cells, battery electrodes, solar PV cells, electrically conductive inks, thermally conductive films and coatings, thermal interface materials, lightweight composites

Product Overview



Product	Producer	Main characteristics	Applications
Polygrene (graphene-based polymer)	2-DTech Limited	Polymer compounds and masterbatches featuring different types of polymers together with different grades and weight loadings of graphene	Suitable for extrusion, moulding and 3D printing processes
GRAPHINK1 (conductive ink)	2-DTech Limited / Cambridge Graphene Limited	Water based, environmentally friendly, non-toxic, low viscosity (0.003-0.004 Pa.s at 100s-1) ink containing few-layer graphene (thickness - < 3 nanometers, lateral size - 80-500 nanometers, graphene content - 0.2-0.5 mg/ml) for flexible electronics	Suitable for inkjet printing, vacuum filtration, meyer bar coating deposition methods
GRAPHINK2 (conductive ink)	2-DTech Limited / Cambridge Graphene Limited	Water based, environmentally friendly, non-toxic, concentrated (viscosity - 0.6 Pa.s at 100s-1) ink containing graphene and graphite nanoplatelets (thickness - about 10 nanometers, lateral size - about 1000 nanometers, graphene content - 100 mg/ml) for flexible electronics	Suitable for flexo, gravure, screen printing, blade, meyer bar coating deposition methods





As highlighted in their annual report 2019:

- 13 new graphene application collaborations and agreements secured with partners based in the UK and overseas in 2019
- Acquisition of Gnanomat S.L., a Spanish developer of graphene-based energy storage technology
- Establishment of Versarien Graphene Inc., a US subsidiary to exploit opportunities in North America
- Launch of PolygreneTM, a new graphene enhanced polymer to improve thermal and electricity conductivity

References:

- 1. http://www.versarien.com/files/1415/6631/0537/Versarien_plc_Annual_Report_2019.pdf
- 2. https://www.2-dtech.com/wp-content/uploads/2019/04/Graphene-Datasheet-3.4_v3.pdf
- 3. https://www.2-dtech.com/wp-content/uploads/2018/11/Polygrene.pdf
- 4. http://www.cambridgegraphene.com/#what-we-do

Elcora Advanced Materials

Company: Elcora Advanced Materials Website: <u>https://www.elcoracorp.com</u> Headquarters: Bedford, Canada Contact: Bedford, Canada



Overview

Elcora Advanced Materials, founded in 2011, is a Canadian graphite and graphene company. The company operates a graphite mine and processing facility in Sri Lanka and owns a cost-effective, commercially scalable graphite conversion to graphene process. At present, the company produces about 500 tonnes of graphite a year, and its processing facility performs acid- and alkaline-free grinding, flotation, dewatering, and product load-out refining activities.

letrics	Product type:	Powders/suspension	Production capacity:	N/A
Key M	Production methods:	Exfoliation	Applications:	energy storage; coatings; composites; medical; sensing

Product Overview



Product	Туре	Main applications & characteristics
EL-I-C6	Advanced graphite anode powders	Spherical particles for energy storage applications; average particle size - 23.6 microns; BET surface area - 3.16 m²/g; reversible capacity - 355 mAh/g; irreversible capacity - 23 mAh/g; first cycle efficiency - 93.7%; Coulombic efficiency at 40oC - >0.998
EL-2D	Few-layer graphene powder/suspension	high quality, acid- and oxide-free powder/suspension for coating, membrane, and energy storage applications; average sheet thickness - 1-5 nanometers (2-4 layers); average sheet size - < 5 microns; BET surface area - 92 m²/g
EL-MG/5	Micro-graphite	Pure, high quality graphite flakes for energy storage, fire retardant, composite, nuclear, and catalysis applications; average particle size - 1-50 microns; average sheet size - < 5 microns; BET surface area - 92 m²/g
EL-NP	Graphite nanoplatelets	Pure, high quality stacks of graphene sheets for composite, sensing, medical, energy storage, coating applications; average sheet thickness - > 10 layers; average sheet size - < 5 microns





High grade Tanzania graphite project (July 11, 2019)

The company announced it entered into a 10 year venture with Eminent Minerals to exploit 2 high-grade graphite deposits in Tanzania. Under the agreement, Eminent Minerals will provide Elcora with graphite from the project which will be processed on site by Elcora, thus boosting Elcora's supply capability, particularly in the energy storage market.

R&D agreement with Solargise Canada Inc. (June 10, 2019)

The company announced it entered into an R&D agreement with Solargise Canada Inc, a technology-focused manufacturing and utility-scale power project development company. Under the agreement, the companies will use graphite and graphene to improve and augment the efficiency of the solar photovoltaic panels manufactured by Solargise.

Haydale Graphene

Founded: 2010 Website: <u>https://haydale.com</u> Headquarters: Carmarthenshire, UK Contact: info@haydale.com



Overview

Haydale Graphene Industries PLC is a global advanced materials group that develops graphene, boron nitride and silicon carbide micro-fiber and other materials for next generation commercial technologies and industrial materials. The group utilizes plasma functionalization processes to enhance the desired functionalities in its materials and operates through the following 6 global subsidiaries:

- Haydale Limited (R&D operation producing inks and supporting master batch production; UK)
- Haydale Composite Solutions Limited (pre-preg sales and consulting and testing services; UK)
- Haydale Technologies (Korea) Limited (sales servicing the Korean, Chinese and Japanese markets; South Korea)
- Haydale Technologies (Thailand) Company Limited (R&D facility focused on commercial applications; Thailand)
- Haydale Technologies Taiwan Ltd (production facility and technical centre for sales of speciality inks; Taiwan)
- Haydale Technologies, Inc. (production and sales of silicon carbide micro-fibres and whiskers, and ceramic blanks; USA)

etrics	Product type:	N/A	Production capacity:	N/A
Key M	Production methods:	N/A	Applications:	aerospace; automotive; marine; medical; printing inks and coatings; sports





In 2019 the Group generated more than US\$ 4.3 mln. in sales revenue.

In November 2019, the company raised US\$ 550K (approximated) through the issuance of shares.

Shareholder	% held
SUBSTANTIAL	
Quilter Plc	13.36
Anthony Best	8.26
Nicholas Money-Kyrle	5.11
REGISTERED	
Rock (Nominees) Limited	9.07
Cheviot Capital (Nominees) Ltd	7.96
Hargreaves Lansdown (Nominees) Limited	5.99
Barclays Direct Investing Nominees Limited	5.17





The UK-based graphene teams have been developing graphene-based material solutions with enhanced electrical, thermal and mechanical properties for the pre-preg carbon fiber market.



Automotive

Recently, Briggs Automotive Company has officially launched the first production car - Mono R - in the world fully incorporating graphene-enhanced carbon fiber, supplied by Haydale, in every body panel. Furthermore, this new material has been too incorporated in the composite tooling of the latest road-legal, single seat super car, also created by Briggs Automotive Company. The graphene enhanced tooling materials offer:

- better control of the coefficient of thermal expansion
- · superior quality and higher dimensional stability
- · increased tooling lifetime due to better wear resistance

Lastly, such advanced composite materials enable vehicle manufacturers to increase structural rigidity and reduce mass, thus helping meet safety and emissions targets.



Aerospace

The company has demonstrated that the addition of electrically conductive graphene into the resin component of carbon fiber improves the through-thickness electrical conductivity by as much as 6 times, thus becoming attractive for unmanned aerial vehicles wherein such as a material imparts lightning strike protection and electromagnetic interference shielding for on-board electronic systems.





The UK-based graphene teams have been developing graphene-based material solutions with enhanced electrical, thermal and mechanical properties for the pre-preg carbon fiber market.



Marine

Together with its collaborators, Haydale has been working on dispersing graphene into barrier films and coatings and investigating how specific graphene-enhanced coatings can improve boat performance.



Medical

Together with its collaborators, Haydale has been developing graphene enhanced inks and coatings for medical applications, such as print test strips in the self-diagnostic biomedical sensor device market for diabetes monitoring.



Printing inks and coatings

Haydale offers graphene-enhanced polylactic acid filaments with improved speed, strength, quality and accuracy for 3D printing.



Sports

Haydale has been actively developing graphene-enhanced carbon fibre products for sportswear, bicycle frames, skies, tennis racquets



Company: Thomas Swan Website: Link Headquarters: Durham, United Kingdom Contact: Link



Overview

Thomas Swan, founded in 1926, is a British chemical manufacturer. The company operates from 3 hubs in the UK, USA and China and services over 80 countries worldwide. The company produces various types graphene nanoplatelets as well as graphene masterbatches. Its product portfolio consists of the following three divisions:

- Chemical division (anti-oxidants, inks and coatings; leather fungicides; personal and household care; tyre and rubber additives)
- Advanced materials division (graphene; carbon nanotubes; boron nitride)
- Custom manufacture division

etrics	Product type:	powders, dispersion, paste	Production capacity:	20-40 tonnes
Key Mo	Production methods:	Liquid exfoliation	Applications:	coatings and paints; additives; polymer and rubber composites





Product type and description	Grades	
Good quality graphene nanoplatelets dispersed in either ionic or non-ionic liquid; available in powder, dispersion	Elicarb® (powder, dispersion, paste)	lonic graphene nanoplatelets: size - 90% smaller than 9 micrometers; sheet resistance - < 25 Ohm/sq.
or paste forms		Non-ionic graphene nanoplatelets: size - 90% smaller than 9 micrometers; sheet resistance - < 40 Ohm/sq.

A detailed list of all the types of Elicarb® products are presented on the following page.


Product	Description	Surface	Form
PR1507	EliCarb® GNP M1D1507	Anionic surface modifier	Dispersion in water (solids- 9wt.%)
PR1515	EliCarb® GNP F7D1515	Non-ionic surface modifier	Dispersion in water (solids- 9wt.%)
R&D	EliCarb® GNP F10Dxxxx	Ionic /polymeric surface modifier	Dispersion in water (solids- 9wt.%)
R&D	EliCarb® GNP F11D15xx	Non-ionic /polymeric surface modifier	Dispersion in water (solids- 9wt.%)
AM1504	Elicarb® GNP M1S1504	Anionic surface modifier	Paste
PR0953	Elicarb® GNP M1P0953	Anionic surface modifier	Powder
PR0955	Elicarb® GNP M1P0955	Anionic surface modifier	Powder
PR1518	Elicarb® GNP F7P1518	Non-ionic surface modifier	Powder
R&D	Elicarb® GNP F11P15xx	Non-ionic /polymeric surface modifier	Powder
PS1522	Elicarb® GNP F7M1522-10PA6	Non-ionic surface modifier	Masterbatch (10% in PA6)
R&D	Elicarb® GNP F11M15xx-10PA6	Non-ionic /polymeric surface modifier	Masterbatch (10% in PA6)
R&D	Elicarb® GNP FxM15xx-10yyy	Non-ionic surface modifier	Masterbatch (10% in TBD)
SP8100	EliCarb® GNP M1E-[RD3]	Anionic surface modifier	Dispersion - epoxy





News

Additional process patents (13 May 2020):

The company announced that it had expanded its patent portfolio by adding 3 new patents concerning the production of graphene and Boron nitride materials using high shear liquid phase exfoliation by high volume homogeniser technology.

Successful graphene application collaboration (18 February 2020):

The company announced that it together with Graphene Engineering Innovation Centre (Manchester, UK) had succeeded in incorporating graphene in polyamide 6 fiber. This achievement enhanced the range of polymeric solutions and is suited for motors, seat belts or fishing lines.

New graphene collaboration (1 May 2019):

The company announced that it had teamed up with the nano-materials technology manufacturer Graphene Composites Ltd. Thomas Swan will provide the new partner with its graphene for the enhancement of Graphene Composites' GC Shield[™] armour product range for individual protection from bullets and knives.



Founded: 1920 Website: <u>https://firstgraphene.net</u> Headquarters: Perth, Australia Contact: info@firstgraphene.net



Overview

First Graphene Ltd. is an Australian large-scale manufacturer of high-quality graphene and developer of graphene-enhanced products. The company owns a graphite mining facility in Sri Lanka and produces graphene through a proprietary single-step, high-yield process at its manufacturing facility in Australia.

First Graphene heavily invests in downstream graphene markets and works with a number of high-profile research organizations, such as the Graphene Engineering Innovation Centre (at the University of Manchester, UK) to accelerate the development and application of graphene-based products. In the last 9 months (period ended March 31, 2020), the company generated more than US\$ 88,000 (approximated) in sales revenue. The company size is 11-50 employees.

trics	Product type:	Powder	Production capacity:	100 tonnes/year
Key Me	Production methods:	Electrochemical exfoliation	Applications:	Composites; elastomers, fire retardancy; concrete, energy storage; textiles





Product	Description	Average Lateral Size	Sheet Resistance	Applications
PureGRAPH® 20	High purity, defect-free,	20 micrometers	< 10 Ohm/square	Composites;
PureGRAPH® 10	non-aggregated, easy to disperse graphene platelets	10 micrometers		elastomers, fire retardancy; concrete, energy storage; textiles
PureGRAPH® 5		5 micrometers		





News (as highlighted in the quarterly report released on 31 Apr 2020)

- Graphene manufacturing at the production facility in Australia continued safely throughout COVID-19 restrictions.
- Steel Blue, an Australian supplier of work boots, executed a 2-year graphene supply agreement for use in work safety boots.
- Company is continuing field trials of a graphene-reinforced bucket liner with a major iron ore mining company.
- Company is continuing the development of a one-step, high-yield, environmentally-friendly manufacturing method of graphene oxide.

References:

- 1. https://firstgraphene.net/wp-content/uploads/austocks/fgr/2020_04_30_FGR_bab93633b5f0d6a1cdae30ff1d18c85a.pdf
- 2. <u>https://firstgraphene.net/wp-content/uploads/2019/06/PureGRAPH_FirstGraphene_Product-Sheet_Digital-230ct2018.pdf</u>
- 3. https://firstgraphene.net/wp-content/uploads/austocks/fgr/2020_04_30_FGR_4500f681225177e5a310645a6406d8d4.pdf

Applied Graphene Materials

Founded: 2010
Website: Link

Headquarters: Cleveland. UK Contact: <u>info@appliedgraphenematerials.com</u>



Overview

Applied Graphene Materials is a British producer of graphene specialty materials. The company runs a commercial-scale production facility at the Wilton Centre in Redcar, UK, capable of producing high purity graphene using a proprietary, patented process, which is based on sustainable, readily available raw materials, and does not rely on the supply of graphite. Core markets include:

- paints and coatings
- polymers and composites
- functional fluids

In the last 6 months of 2019, the company generated more than US\$ 43,000 in revenue. The company size is 11-50 employees.

etrics	Product type:	powders/water and polymer dispersions	Production capacity:	not specified
Key M	Production methods:	solution-based decomposition of metal alkoxide	Applications:	paints and coatings; polymers and composites; lubricants and functional fluids





Undisclosed investments first came from IP Group, North East Technology Fund and North East POC Fund. Then the company raised additional capital via secondary placings in 2015 and 2017.

Significant Shareholders	% Held
IP Group	19.09
Herald Investment Management	9.61
Hargreaves Lansdown Stockbrokers	9.34
Insight Investment	7.80
Eden Tree Investment	7.59
Ruffer	7.05
Baillie Gifford	4.84
HSDL Stockbrokers	3.52
Interactive Investor	3.22
University of Durham	2.49

Product Overview - Graphene Nanoplatelets



Product	Description	Main Characteristics	Typical Thickness	Typical Lateral Dimensions	Applications
AGNP-10	A mixture of graphene nanoplatelets of various sizes	 Low density graphene powder Moderate oxygen content 	1-10 nanometers	1 15 micromotoro	Suitable for applications requiring enhanced mechanical, barrier,
AGNP-35	A mixture of very thin, crumpled graphene sheets of various sizes	 Ultra low density graphene powder Low oxygen content High surface area 	5-15 atomic layers	1-15 micrometers	and electrical properties

Product Overview - Graphene Dispersions



Genable® 1000 series (for paints and coatings on metallic substrates; composites)

Product	Matrix	Graphene Content	Viscosity	Particle Size (D90)	Shelf Life
Genable® 1000	Epoxy EEW (190g/eq.) resin	10 wt.%	18-25 Pa.s	10-25 microns	12 months
Genable® 1001	Epoxy EEW (250g/eq.) resin	10 wt.%	1.0-2.5 Pa.s	5-15 microns	12 months
Genable® 1030	Butyl acetate	10 wt.%	0.02-0.35 Pa.s	5-15 microns	3 months
Genable® 1031	Xylene	10 wt.%	0.02-0.04 Pa.s	5-15 microns	3 months
Genable® 1032	Methyl ethyl ketone	10 wt.%	0.5-1.7 Pa.s	5-15 microns	3 months
Genable® 1033	Ethyl acetate	10 wt.%	0.01-0.15 Pa.s	5-15 microns	3 months
Genable® 1050	Water	10 wt.%	0.01-0.03 Pa.s	10-20 microns	3 months
Genable® 1200	Epoxy EEW (190g/eq.) resin	1 wt.%	50-75 Pa.s	120-150 microns	12 months
Genable® 1201	Epoxy EEW (250g/eq.) resin	1 wt.%	65-100 Pa.s	10-20 microns	12 months
Genable® 1230	Butyl acetate	0.5 wt.%	0.2-2.5 Pa.s	6-15 microns	6 months
Genable® 1231	Xylene	0.5 wt.%	0.3-1.0 Pa.s	6-28 microns	6 months
Genable® 1232	Methyl ethyl ketone	0.5 wt.%	0.9-2.6 Pa.s	10-35 microns	6 months
Genable® 1233	Ethyl acetate	0.5 wt.%	1.0-3.0 Pa.s	8-15 microns	6 months
Genable® 1250	Water	0.5 wt.%	< 0.4 Pa.s	12-20 microns	6 months

Product Overview - Graphene Dispersions



Genable® 2000 series (for paints and coatings on aluminium substrates)

Product	Description	Matrix	Viscosity	Particle Size (D90)	Shelf Life	Applications
Genable® 2400	Stable dispersions of graphene nanoplatelets in	Epoxy EEW (190g/eq.) resin	50-75 Pa.s	120-150 microns	3 months	Suitable for paintings and coatings
Genable® 2401	epoxy resins	Epoxy EEW (250g/eq.) resin	65-100 Pa.s	10-20 microns	3 months	(outstanding barrier properties, anti-corrosive) applications on aluminium substrates

Genable® 3000 series (for paints and coatings on non-metallic substrates)

Product	Description	Matrix	Graphene Content	Viscosity	Particle Size (D90)	Shelf Life	Applications
Genable® 3000	stable dispersions of graphene	Epoxy EEW (190g/eq.) resin	5wt.%	20-25 Pa.s	20-0 microns	3 months	Suitable for paintings and coatings (active,
Genable® 3001	nanoplatelet s in epoxy resins	Epoxy EEW (250g/eq.) resin	5wt.%	20-25 Pa.s	20-40 microns	3 months	anti-corrosive) applications on non-metallic substrates



Genable® 4000 for polymer composite applications

Product	Description	Matrix	Viscosity	Shelf Life	Other Characteristics	Applications
Genable® 4300	Low density thermal paste adhesives and masterbatch additives	Epoxy (2 part with amine hardener)	Moderate	12 months	Lap shear strength: > 5 Mpa Thermal conductivity: > 3 (W/m.K)	Suitable for polymer composite applications
Genable® 4400		Epoxy (2 part with amine hardener)	High	12 months	Lap shear strength: > 5 Mpa Thermal conductivity: > 5 (W/m.K)	

Product Overview - Miscellaneous Graphene Dispersions



Matrix	Туре
Vinyl ester	Resin
Benzoxazine	Resin
UV curable	Resin
Polytetrafluorethylene	Resin
Polyurethane	Resin
Polyester	Resin
Alkyd	Resin
Acrylic	Resin
Polyol	Solvent
Hexanediol diacrylate	Solvent
Methyl methacrylate	Solvent
Waterborne paint	Solvent
Propylene glycol methyl ether	Solvent
Glycol ether	Solvent
Toluene	Solvent
Isopropyl alcohol	Solvent
White spirit	Solvent

Matrix	Туре
Acetone	Solvent
Tripropylene glycol diacrylate	Solvent
Ethanol	Solvent
Dimethyl sulfoxide	Solvent
Cyclohexanone	Solvent
Dipropylene glycol diacrylate	Solvent
Mono ethylene glycol	Solvent
Dichlormethane	Solvent
Paraffin wax	Wax
Group I base oil	Lubricant
Group II base oil	Lubricant
Group III base oil	Lubricant
Group IV base oil	Lubricant
Group V base oil	Lubricant
Greases	Lubricant
Solventborne paint	Paint





As highlighted in the Interim Results for the last 6 months of 2019 released on 25 Mar 2020:

- In partnership with Alltimes Coating, a specialist in protective coatings for buildings, Applied Graphene Materials developed an enhanced, anti-corrosive coating that comes with a 30 year warranty. This cost-effective coating was designed for industrial and commercial roofs.
- In collaboration with Composite Tooling Engineering Solutions and SHD Composites, Applied Graphene Materials successfully integrated graphene sheets into a 10-meter-long advanced fiber placement composite tool. Graphene was incorporated as liquid dispersion into matrix through the advanced structural ink printing technology and was shown to significantly improve the lifetime of the composite tool.

References:

- 1. <u>https://ir.q4europe.com/Solutions/AppliedGrapheneMaterials/2152/newsArticle.aspx?storyid=14645128</u>
- 2. <u>https://patents.justia.com/patent/9932227</u>
- 3. <u>https://www.appliedgraphenematerials.com/products/graphene-nanoplatelets/</u>
- 4. https://www.appliedgraphenematerials.com/products/standards-genable-dispersion/
- 5. https://www.appliedgraphenematerials.com/products/development-dispersions/



Founded: 2010 Website: <u>http://www.talgagroup.com/</u> Headquarters: Perth, Australia Contact: info@talgagroup.com



Overview

Talga Group is an advanced material company that focuses on developing graphene and graphite enhanced products for the coatings, battery, construction and polymer composites markets. The company owns ultra-high grade and large natural graphite resources (48.1 megatonnes of graphitic ore) and mining logistics in Sweden, and proprietary cost-effective graphite processing methods. Talga Group is comprised of:

- Talga Graphene AB & Talga Battery Metals AB (operate the natural mineral resource assets; Sweden)
- Talga Technologies Limited (conducts product research and development; United Kingdom)
- Talga Advanced Materials GmbH (runs the processing technology test facility and graphene plant operations; Germany)
- In 2019, the company generated US\$ 1.66 million. in revenue; Company size is 11-50 employees.

etrics	Product type:	Powders	Production capacity:	N/A
Key M	Production methods:	Electrochemical exfoliation	Applications:	Energy storage; coatings; composites and resins; building materials





In 2019, Talga Group completed issuance of shares totalling US\$ 5.45 million.

Significant Shareholders	% Held
Smedvig Talga L.P.	10.47
Lateral Minerals Pty Ltd < Thompson Family A/C>	5.89
JP Morgan Nominees (Australia) Ltd	5.22
Pelmer Securities S A	3.76
Citicorp Nominees Pty Ltd	3.56
BNP Paribas Nominees Pty Ltd	3.36
HSBC Custody Nominees (Australia) Limited	2.96
Kamberg Investments Ltd	2.61
Yandal Investment Pty Ltd	2.05



Product	Main characteristics
Micro graphite	
Talphite ®	High purity micro-graphite using proprietary electrochemical exfoliation and concentration process
Graphene	
TalnodeTM - Si	enhanced performance graphene silicon anode for Li-ion batteries
Talphene® Pre-treatment	anti-corrosive coating, enhanced with graphene nanoplatelets to replace chrome and other toxic metals
Talphene® Epoxy	improved strength anti-corrosive coating, enhanced with graphene nanoplatelets/flakes
Talphene® Inks	improved electrical conductivity ink, enhanced with graphene nanoplatelets/flakes, for printed electronics, sensors and smart labels
Talphene® Admixtures	improved mechanical performance additive, containing graphene nanoplatelets/flakes, for cement
Talphene® additive for thermoplastic polyurethane	graphene nanoplatelets/flakes for thermoplastic urethane; suited for healthcare and eco-friendly marine coating applications





As highlighted in the quarterly activities review ended 31 Mar 2020:

Completion of the Talga pilot-scale processing program of 60 tonne graphite ore. The program achieved the desired product targets, so now the produced graphite concentrate has progressed to the next stage of converting the concentrate into Talga's flagship anode product (Talnode[©]-C) for on-going anode market development and customer qualification programs.

Ongoing trials of Talga's newly developed Talcoat® graphene additive for maritime primer coatings on 2 ocean going vessels at sea. Other interested parties across several sectors of the global coating industry have also received Talcoat® product samples for testing.

References:

- 1. <u>http://www.talgagroup.com/irm/PDF/2541_0/annualreport2019</u>
- 2. <u>http://www.talgagroup.com/irm/PDF/f446c937-ce9b-459d-9c0c-80b9dd66c2ff/TalgaPresentationatIDTechExShowUSA20</u> 19
- 3. http://www.talgagroup.com/irm/PDF/14f7891d-4335-4619-84a9-d1c4bb1554bf/2018AnnualGeneralMeetingPresentation
- 4. <u>http://www.talgagroup.com/irm/PDF/f69bb948-f311-46ec-9011-0a7dd7d3296a/QuarterlyActivitiesReportandAppendix5B</u> <u>31March2020</u>



Founded: 2011 Website: http://www.grafoid.com Headquarters: Ontario, Canada Contact: info@grafoid.com



Overview

Grafoid Inc. is a graphene research, development and investment company that invests in, manages and develops markets for processes that produce economically scalable and functional graphene and its products. The company utilizes unprocessed graphite ore in a cost-effective patented one-step process to yield near defect-free, high-energy density MesoGraf[™] graphene for further applications. Company size is 11-50 employees. In 2017, Grafoid received US\$ 5.74 million (approximated) from the Canadian Government to build the world's first automated graphene production line. Company subsidiaries are presented below.

- Braille Battery Inc. (a developer and manufacturer of advanced lightweight lithium-ion batteries)
- Alcereco Corporation (a developer of advanced composite materials, alloys and coatings)
- MuAnalysis Inc. (a provider of analytical and laboratory services)
- Graflow Inc. (a developer of graphene-polymer composite technologies)
- GrafCoat GrafeneX Coatings (a developer of electrically and thermally conductive graphene coatings)
- PHOS Solar Systems Inc. (a developer of graphene-based solar energy systems)
- Grafprint3D Inc. (a producer of metallic and polymer fine powders and graphene enhanced polymer filaments for 3D printing)
- Surfacene Environmental Inc. GPURE Membranes (a developer of graphene foam)

etrics	Product type:	Powders	Production capacity:	N/A
Key Me	Production methods:	Exfoliation	Applications:	Energy storage; coatings; membranes; composites



Product	Grades
Graphene	MesoGrafTM
Graphene oxide	G-NOX Ultra (aerogel) G-NOX Ultra (dispersion in water) G-NOX Ultra (dispersion in an organic solvent)
Graphene ink	M-JET (conductive inkjet printing ink) MP-LEX (conductive 3D printing ink) MC-LEX (conductive 3D printing ink)

Product Overview - Graphene Oxide



Product	Description	Main Characteristics
G-NOX Ultra (aerogel)	Graphene oxide aerogel based on monolayer graphene oxide sheets with the sizes ranging between 1-11 micrometers;	 oxygen content - 31-34% long shelf life easy to process offered in amounts of 100 / 250 / 500 / 1000 / 5000 milligrams
G-NOX Ultra (dispersion in water)	Graphene oxide aqueous dispersion containing monolayer graphene oxide sheets with the sizes ranging between 1-10 micrometers;	 oxygen content - 31-34% available in 1 or 4 milligrams/milliliter concentrations offered in amounts of 100 /200 / 400 milliliters
G-NOX Ultra (dispersion in an organic solvent)	Graphene oxide dispersion in dimethyl formamide or N-methyl-2- pyrrolidone solvents containing monolayer graphene oxide sheets with the sizes ranging between 1-10 micrometers;	 oxygen content - 31-34% available in 1 or 4 milligrams/milliliter concentrations offered in amounts of 100 / 200 / 400 milliliters

Product Overview - Graphene Inks



Product	Description	Main characteristics	Applications
M-JET	MesoGrafTM graphene sheets with the sizes ranging between 1-200 micrometers in tripropylene glycol diacrylate solvent	 Viscosity at room temperature - 0.01-0.02 Pa.s Surface tension - 33-36 mN/m Resistivity - 0.01-1.0 ohm.cm Optimal curing conditions - 150oC for 2 minutes 	Suited for any substrate (i.e. wood, paper, cardboard, fabrics, plastics, and glass)
MP-LEX	MesoGrafTM graphene sheets in poly(lactide-co-glycolide) (molar mass 100-200 kDa)	 Viscosity at room temperature - 1.1-1.3 Pa.s Surface tension - 25-40 mN/m Resistivity - 0.005-0.1 ohm.cm Curing time at room temperature - less than 3 seconds 	Designed for layer-by-layer 3D printing assembly via direct ink writing/liquid extrusion technique
MC-LEX	MesoGrafTM graphene sheets in ethyl cellulose	 Viscosity at room temperature - 1.1-1.7 Pa.s Surface tension - 27-39 mN/m Resistivity - 0.05-0.1 ohm.cm Curing time at 80oC - 2-30 seconds, at 120oC - 2-15 seconds 	Designed for layer-by-layer 3D printing assembly via direct ink writing/liquid extrusion technique





Based on the latest release of their corporate update, 27 Aug 2019:

- Launched an innovative suite of oxidized graphene products, GNOXTM
- Launched, a new company, of Grafprint3D Inc., that offers a portfolio of products and solutions based on the proprietary MesografTM technology for the additive manufacturing and 3D printing market
- Entered into a strategic partnership with Liquinex, a company specializing in wastewater engineering needs, to provide commercial scale water treatment solutions using MesografTM graphene-based filtration technology.

References:

- 1. https://grafoid.myshopify.com/collections/ultra-graphene-oxide-aerogel
- 2. <u>https://grafoid.myshopify.com/collections/ultra-graphene-oxide-h2o-dispersion</u>
- 3. https://grafoid.myshopify.com/collections/ultra-graphene-oxide-organic-solvent
- 4. <u>https://www.grafprint3d.com/pages/m-jet</u>
- 5. https://www.grafprint3d.com/pages/mp-lex
- 6. https://www.grafprint3d.com/pages/mc-lex
- 7. http://www.grafoid.com/category/news-releases/



Company: G6 Materials Website: <u>https://g6-materials.com</u> Headquarters: New York, USA Contact: info@g6-materials.com



Overview

G6 Materials Corp, founded in 2014, is a canadian developer and manufacturer of graphene and other 2D-materials. The company boasts more than 20,000 customers worldwide, a comprehensive IP portfolio and established research and manufacturing facility. It offers:

- R&D materials; over 100 graphene and related products for a broad range of applications through the subsidiary Graphene Laboratories Inc.;
- 3D printing; a portfolio of 3D printing filaments
- High performance epoxies
- Fine organic chemicals; a broad range of chemicals to the R&D sector in pharmaceutical/agricultural industries, academic institutions

Metrics	Product type:	powders, solutions, foams, aerogel, chemical vapor deposition	Production capacity:	N/A
Key I	Production methods:	Carbon vapor deposition; chemical exfoliation	Applications:	conductive adhesives; composites; coatings; energy storage; biosensing; catalysis





Product	Grades
Conductive adhesives	G6-EPOXYTM
Advanced materials and composites	N/A
Organic chemicals	ChemApproachTM
 A range of R&D graphene materials: chemical vapor deposition graphene graphene nanopowder graphene sheets graphene solutions 3D graphene foams graphene aerogel (reduced) graphene oxide powders 	N/A



Product	Grades
Chemical vapor deposition (CVD) graphene	Mono-, few-layer graphene produced via chemical vapor deposition (CVD) on nickel/copper foil, film, and foam; graphene on dielectric substrates including glass, polytetrafluorethylene (PET), and silica/silicon (SiO ₂ /Si) wafers.
Types of CVD	
CVD graphene on copper foil	High quality, predominantly single layer graphene on both sides of the copper foil, which is 25 micron in thickness; available in 2"x2", 4"x2" and 4x4" sheet sizes
CVD graphene on nickel foil	Non-uniform, multi layer graphene films (thickness - 500-800 nanometers) on nickel foil, which is 25 micron in thickness; available in 2"x2' sheet size
CVD graphene on nickel	Non-uniform, few monolayers (1-7 layers) thick graphene sheets on nickel/SiO ₂ /Si substrate (100 mm in diameter)
CVD graphene on 90 or 285 nanometers silica wafer	Polycrystalline graphene films covering 95% of SiO ₂ ; sheet resistance - 660-1500 Ohms/square; available in the pack of 5 or 10
CVD graphene on SiO₂ /Si wafer	2 layers of primarily monolayer polycrystalline graphene; contains minor holes and organic residue; sheet resistance - 215-700 Ohms/square; available in the pack of 4 or 8





Product	Grades
Types of CVD	
CVD graphene/hexagonal boron nitride heterostructure on SiO₂ /Si wafer	Predominantly monolayer sheets; contain minor holes and organic residue; sheet resistance - 430-800 Ohms/square; available in the pack of 4 or 8
CVD graphene on SiO₂ wafer	Continuous, with occasional holes and crack, multilayer graphene sheets; 660-1500 Ohms/square; available in the pack of 5 or 10
CVD graphene on glass substrate	Monolayer polycrystalline graphene film; contains minor holes and organic residue; sheet resistance - 660-1500 Ohms/square; available in 1"x1‴ and 2"x2" sheet sizes
CVD graphene on PET substrate	Monolayer polycrystalline graphene film; contains minor holes and organic residue; sheet resistance - 660-1500 Ohms/square; PET thickness - 175 microns; available in 1"x1‴ sheet sizes
CVD graphene-nanosilver wires on PET substrate	Monolayer polycrystalline graphene film on silver nanowires/PET substrate; contains minor holes and organic residue; sheet resistance - 40-60 Ohms/square; PET thickness - 175 microns; available in 4x4 cm sheet sizes
Graphene nanopowders (GNPS)	Graphene nanoplatelets a few microns in lateral size with the thickness ranging from a few nanometers to tens of nanometers.



Product	Grades
Grades/Types of GNPs	
AO1 grade	Good quality, low oxygen content (< 2.5 %) GNP's; average thickness - 1.6 nanometers (< 3 monolayers); average flake size - 10 microns; specific surface area - 400-800 m²/g; available in 0.5/1.0 gram jars
A12 grade	High quality GNP's; average thickness > 3 nanometers (3-8 monolayers); average flake size - 2-8 microns; specific surface area - 400-800 m²/g; available in 5/25 gram jars
AO₂ grade	Good quality GNP's; average thickness - 8 nanometers (20-30 monolayers); average flake size - 5 microns; specific surface area - > 15 m²/g; available in 5/25/50 gram jars
C1 grade	Good quality GNP's; average thickness - 5-60 monolayers; average flake size - 5-25 microns; specific surface area - 60m²/g; available in 25/100/500 gram jars
AO₃ grade	Good quality GNP's; average thickness - 30-50 monolayers; average flake size - 5 microns; specific surface area - 80m²/g; available in 5/25/100 gram jars
AO4 grade	Good quality GNP's; average thickness - 60 nanometers; average flake size - < 7 microns; specific surface area - < 40 m²/g; available in 25/100 gram jars



Product	Grades
Grades/Types of GNPs	
Electrically and thermally conductive granulated graphene	High quality GNP's; average size - 5 millimeters; available in 100 gram jars
GF-6 grade	Good quality, fluorinated GNP's; average thickness - 12 nanometers; average flake size - 1-5 microns; specific surface area - 65 m²/g; fluorine content - 6 wt.%; available in 1/5 gram jars
Nitrogen HDPlasTM	Good quality, nitrogen functionalized GNP's; average thickness - < 50 nanometers; average flake size - 0.3-5.0 microns; specific surface area - 20 m²/g; available in 5 gram jars
Oxygen HDPlasTM	Good quality, oxygen functionalized GNP's; average thickness - < 50 nanometers; average flake size - 0.3-5.0 microns; specific surface area - 20 m²/g; available in 5 gram jars
Carboxyl HDPlasTM	Good quality, carboxyl functionalized GNP's; average thickness - < 50 nanometers; average flake size - 0.3-5.0 microns; specific surface area - 20 m²/g; available in 5 gram jars
Ammonia HDPlasTM	Good quality, ammonia functionalized GNP's; average thickness - < 50 nanometers; average flake size - 0.3-5.0 microns; specific surface area - 20 m²/g; available in 5 gram jars
Argon HDPlasTM	Good quality, argon functionalized GNP's; average thickness - < 50 nanometers; average flake size - 0.3-5.0 microns; specific surface area - 20 m²/g; available in 5 gram jars
Fluorocarbon HDPlasTM	Good quality, fluorocarbon functionalized GNP's; average thickness - < 50 nanometers; average flake size - 0.3-5.0 microns; specific surface area - 20 m²/g; available in 5 gram jars



Product	Grades	
Grades/Types of GNPs		
Conductive graphene sheets	Good quality conductive graphene sheets; average thickness - 25 microns; thermal conductivity - 1300-1500 W/m.K (x-y plane), 13-15 W/m.K (thickness direction); sheet resistance - 0.03 Ohm/square; tensile strength - 30 MPa; available in 8"x4"/8"x8" sheet, 5/10/20 pack sizes	
Graphene dispersions	Conductive graphene dispersion n-butyl acetate: high quality GNP's; average thickness - 7 nanometers; GNP's content - 23 wt.% ; available in 100/200 ml jars	
	Pristine graphene monolayer flakes in ethanol: high quality graphene sheets; ultra low oxygen content; no surfactants; average thickness - 1 monolayer; average size - 0.5 microns; graphene concentration - 1 mg/L; available in 50 ml jars	
CVD graphene on lacey Carbon TEM grids	CVD graphene grown on Nickel substrate subsequently deposited on lacey Carbon grid, 300 mesh; thickness - 1-6 monolayers; typical graphene coverage - 60-95%; available in the pack of 5 or 25	
CVD graphene on Copper TEM grids	CVD graphene grown on Nickel substrate subsequently deposited on copper grid, 2000 mesh; thickness - 1-6 monolayers; typical graphene coverage - 60-95%; available in the pack of 5 or 25	





Product	Grades
Grades/Types of GNPs	
Freestanding 3D-graphene foams	Carbon content - 99%; thickness - 1.2 millimeters; density - 4 mg/cm³; pore size - 580 microns; sample size - 2"x2"
CVD graphene on Nickel foam	Thickness - 1.2 millimeters; density - 320 mg/cm³; pore size - 580 microns; sample size - 2"x2" or 2"x4"
Graphene-polydimethylsiloxane (PDMS) flexible foam	Comprised of CVD grown graphene foam core embedded with PDMS; carbon content - 95%; PDMS content - 5%; thickness - 1.2 millimeters; density - 85 mg/cm ³ ; volume resistivity - 6 Ohm.cm ; sample size - 3.0"x1.5"
Graphene aerogel	Made by reduction of graphene oxide; density - 12.5 mg/cm ³ ; electrical conductivity - 1-10x10-4 S/cm; available in 75/100 milligrams round shape with the diameter of 0.9" and height - 0.6"; 850 milligrams rectangular shape 2.80"x2.60"x0.52"
Graphene oxide (GO) powders/flakes/films	GO foam granules: purity - > 99%; density - 30mg/cm³; average granule size - 3-10 millimeters; sample size - 0.5 gram
	Single layer GO: composition - 79% Carbon and 20% Oxygen; average flake size - 0.2-2.0 microns; thickness - > 80% monolayer flakes; sample size - 0.5/1.0 gram



Product	Grades
Grades/Types of GNPs	
GO solutions/pastes	Single layer GO dispersion in water: concentration - 500 mg/L; composition - 79% Carbon and 20% Oxygen; flake size - 0.3-0.7 microns; thickness - > 80% monolayer flakes; available in 60/175 milliliters jars
	Highly concentrated single layer GO dispersion in water: concentration - 500 mg/L; composition - > 46% Carbon and < 46 % Oxygen; flake size - 0.5-5.0 microns; thickness - > 60% monolayer flakes; available in 175/1000 milliliters jars
	GO paste: concentration - 30-35 g/L; flake size - 0.5-5.0 microns; thickness - > 80% monolayer flakes; available in 30/60 milliliters jars
Nano GO	Nano GO powder: size - 90-200 nanometres; thickness - > 99% 1 nanometer; purity - > 99%; available in 100 milligrams jars
	Nano GO solution in water: concentration - 1g/L; size - 90-200 nanometres; thickness - > 99% 1 nanometer; purity - > 99%; available in 125 milliliters jars





Product	Grades
Grades/Types of GNPs	
High porosity Reduced GO	High porosity GO: solid content - 98%; specific area - 400 cm²/g; average thickness - 1 monolayer; average size - 3-10 microns; flakes contain multiple holes and openings; available in 0.25/0.50 grams jars
	High surface area RGO: solid content - 98%; specific area - 833 cm²/g; average thickness - 1 monolayer; average size - 3-5 microns; Carbon/Oxygen ratio - 10.5;; available in 75 milligrams jars
	RGO foam granules: purity - 99%; density - 20 mg/cm³; average granule size - 3-10 millimeters; volume conductivity - 5 Ohm.cm; available in 0.5 gram jars





News (as highlighted in the company's presentation released in Jan 2020)

- The company generated more than US\$ 900k in sales revenue in 2019. In March 2019, the company raised US\$ 220k + through the issuance of shares.
- Company's name changed from Graphene 3D Lab Inc to G6 Materials Corp. to reflect changes in the expanded business focus (Winter 2020)
- Developed high-performance graphene/glass and carbon fiber composites with marine vessel industry partner (Summer 2019)
- Finalized technology transfer agreement with major pharmaceutical company and received royalty payment (Winter 2019)

References:

1. <u>https://graphene-supermarket.com/Research-Materials/</u>



Company: Graphnea Website: Link Headquarters: Paseo Mikeletegi 83, 20009 - San Sebastián, SP Contact: <u>Link</u>



Overview

Graphenea, founded in 2010, is a Spanish graphene producer and developer of graphene applications in more than 60 countries worldwide. The company operates from 2 facilities in Spain and USA and offers:

- · Chemical vapor deposition grown graphene films
- Graphene field-effect transistors chips
- Graphene foundry services
- Graphene oxides

It also is a partner of the Graphene Flagship, the international organization that unites and supports graphene manufacturers and developers.

letrics	Product type:	Films	Production capacity:	N/A
Key M	Production methods:	chemical vapor deposition; chemical graphite oxidation	Applications:	Bioeletronics; photodetectors; chemical/magnetic/biosensors





Product	Main characteristics	Applications	
Easy Transfer: monolayer graphene on polymer film	Transparent (> 97% transparency) monolayer graphene sheets on polymer substrate; substrate coverage - > 97%; sheet resistance on SiO ₂ /Si - 450±40 Ohms/sq; FET Electron Mobility on Al ₂ O ₃ passivated SiO ₂ /Si: 6900 cm ² /V.s; FET Electron Mobility on SiO ₂ /Si: 3760 cm ² /V.s	Suited for research, flexible batteries, electronics, aerospace industry, micro/nanocmechanical systems, microactuators, conductive coatings applications	
Monolayer graphene on Copper film	Transparent (> 97% transparency) monolayer graphene sheets on Copper substrate; substrate coverage - > 97%; sheet resistance on SiO ₂ /Si - 450±40 Ohms/sq; FET Electron Mobility on Al ₂ O ₃ passivated SiO ₂ /Si: 6900 cm ² /V.s; FET Electron Mobility on SiO ₂ /Si: 3760 cm ² /V.s	Suited for research, flexible batteries, electronics, aerospace industry, micro/nanocmechanical systems, microactuators, conductive coatings applications	
Monolayer graphene on thin Copper film on sapphire (2" wafer)	Transparent (> 97% transparency) monolayer graphene sheets on copper/sapphire substrate; substrate coverage - > 97%; grain size - up to 30 µm²; Copper/sapphire thickness - 430 µm;	Suited for research, (opto)eletronics, aerospace industry, sensors, micro/nanocmechanical systems, microactuators	
Suspended graphene on cavities	Tailored made product as per customer requirements; transparent (> 97% transparency) monolayer graphene sheets; grain size - up to 20 µm Substrate requirements: size - up to 1.5 x 1.5 cm; cavity size - up to 30 µm; minimum cavity depth - 500 nm; temperature resistance - must withstand 450oC		





Product	Main characteristics	Applications
Monolayer graphene on Copper with poly(methyl methacrylate) coating	Transparent (> 97% transparency) monolayer graphene sheets on copper substrate with polymeric coating; substrate coverage - > 97%; sheet resistance on SiO ₂ /Si - 450±40 Ohms/sq; FET Electron Mobility on Al ₂ O ₃ passivated SiO ₂ /Si: 6900 cm ² /V.s; FET Electron Mobility on SiO ₂ /Si: 3760 cm ² /V.s; poly(methyl methacrylate) thickness - 60 nanometers	Suited for research, flexible batteries, electronics, aerospace industry, micro/nanocmechanical systems, microactuators, conductive coatings applications
Monolayer graphene on SiO₂/Si substrate	Transparent (> 97% transparency) monolayer graphene sheets on SiO ₂ /Si substrate; substrate coverage - > 97%; sheet resistance on SiO ₂ /Si - 450±40 Ohms/sq; FET Electron Mobility on Al ₂ O ₃ passivated SiO ₂ /Si: 6900 cm ² /V.s; FET Electron Mobility on SiO ₂ /Si: 3760 cm ² /V.s; grain size - up to 20 μ m; available SiO ₂ /Si thickness - 90 or 300 nanometers	Suited for research, (opto)eletronics, plasmonics and nanophotonics, bionsensors, bioeletronics, aerospace industry, micro/nanocmechanical systems applications
Monolayer graphene on quartz	Transparent (> 97% transparency) monolayer graphene sheets on quartz; substrate coverage - > 97%; sheet resistance on SiO ₂ /Si - 450±40 Ohms/sq; FET Electron Mobility on Al ₂ O ₃ passivated SiO ₂ /Si: 6900 cm ² /V.s; FET Electron Mobility on SiO ₂ /Si: 3760 cm ² /V.s; grain size - up to 20 µm; quartz thickness - 500 µm	Suited for solar cells, touch screens and displays, photodetectors, light harvesting devices
Product Overview



Product	Main characteristics	Applications
Monolayer graphene on polyethylene terephthalate or polyethylene naphthalate	Transparent (> 97% transparency) monolayer graphene sheets on polymer substrate; substrate coverage - > 97%; sheet resistance on polyethylene terephthalate - 580±50 Ohms/sq; sheet resistance on polyethylene naphthalate - 750±50 Ohms/sq; FET Electron Mobility on Al ₂ O ₃ passivated SiO ₂ /Si: 6900 cm ² /V.s; FET Electron Mobility on SiO ₂ /Si: 3760 cm ² /V.s grain size - up to 20 μ m; polyethylene terephthalate thickness - 250 μ m; polyethylene naphthalate thickness - 125 μ m	Suited for research, flexible displays for organic solar cells, organic light-emitting diodes, optoelectronic devices, indium tin oxide replacement
Multilayer graphene on SiO ₂ /Si, quartz or polyethylene terephthalate substrates	Transparent (> 94% transparency) bilayer and trilayer graphene sheets on polymeric, SiO ₂ /Si or quartz substrate; substrate coverage - > 97%; bilayer sheet resistance - 188±3 Ohms/sq; trilayer sheet resistance - 126±6 Ohms/sq; grain size - up to 20 µm; polyethylene terephthalate thickness - 250 µm; quartz thickness - 500 µm; SiO ₂ /Si thickness - 300 nanometers	Suited for (organic) light-emitting diodes, solar cells, transistors and electronics applications
Monolayer graphene on Silicon nitride substrate	Transparent (> 97% transparency) monolayer graphene sheets on Silicon nitride; substrate coverage - > 97%; sheet resistance - 576±172 Ohms/sq; Hall electron mobility on Silicon nitride - 1432±428 cm ² /V.s; grain size - up to 20 µm; Silicon nitride thickness - 150 nanometers; substrate resistivity -10-20 Ohm.cm;	Suited for research, (opto)eletronics, plasmonics and nanophotonics, photodetectors, bionsensors, bioeletronics, aerospace industry, micro/nanocmechanical systems applications





Product	Main characteristics	Applications
Graphene oxide dispersion in water	Obtained through chemical oxidation of graphite; particle size - < 10µm; concentration - 0.4 wt% solids; monolayer content (measured in 0.05 wt%) - >95%; carbon content - 49-56%; oxygen content - 41-50%; sulfur content - 2-4%	Suited for research, polymer composites, batteries, biomedical applications, solar cells, supercapacitors, support for metallic catalysts, low permeability materials, biosensors
Highly concentrated graphene oxide in water	Obtained through chemical oxidation of graphite; particle size - 90% smaller than 33 µm; concentration - 2.5 wt% solids; monolayer content (measured in 0.05 wt%) - >95%; carbon content - 49-56%; oxygen content - 41-50%; sulfur content - 2-4%	Suited for polymer, ceramic, cement composites
Graphene oxide powder	Obtained through chemical oxidation of graphite; particle size - 90% smaller than 27 µm; carbon content - 49-56%; oxygen content - 41-50%; sulfur content - 2-4%	Suited for research, polymer composites, batteries, biomedical applications, solar cells, supercapacitors, support for metallic catalysts, low permeability materials, biosensors





Product	Main characteristics	Applications
Reduced graphene oxide powder	Obtained through chemical, thermal or irradiation reduction of graphene oxide; particle size - 90% smaller than 15 µm; carbon content - 77-87%; oxygen content - 13-22%; sulfur content - 0%	Suited for research, batteries, biomedical applications, printable electronics; supercapacitors
Graphene oxide film	Obtained by filtration of monolayer graphene dispersion; diameter - 4 cm; thickness - 10-13 µm;carbon content - 49-56%; oxygen content - 41-50%; sulfur content - 2-4%	Suited for research, biomedical, membrane applications
Amine functionalized graphene oxide	Improved dispersibility in polymer matrices, amine functionalized graphene oxide powder; insoluble, only dispersible at low concentrations (< 0.1 mg/mL) in N-methyl-2-pyrrolidone, dimethyl sulfoxide, dimethylformamide solvents; carbon content - 65-74%; oxygen content - 16-22%; nitrogen content - 2-4%; hydrogen content - 6-9%	Suited for polymers, CO2 capture, biomedical applications





Product	Product Main characteristics	
GFET-S10 chip	Graphene field-effect transistors; 36 graphene devices distributed in a grid pattern on the chip; 30 devices have a Hall-bar geometry and 6 - 2-probe geometry; chip dimensions - 10 x 10 mm; chip thickness - 675 μ m; gate oxide thickness - 90 nm; gate oxide material - SiO ₂ ; resistivity of substrate - 1-10 Ohm.cm; metallization - Chromium/Gold 2/50 nm; graphene field-effect mobility - >1000 cm ² /V.s; Dirac point - <50 V; minimum working devices - >75 %; maximum gate-source voltage - ± 50 V; maximum temperature rating - 150 °C; maximum drain-source current density - 107A.cm-2;	Suited for photo / magnetic / biosensing applications
GFET-S20 chip	Graphene field-effect transistors for measurements in liquid medium; 12 graphene devices encapsulated on metal pads; chip dimensions - 10 x 10 mm; chip thickness - 675 μ m; number of graphene transistors - 36 per chip; gate oxide thickness - 90 nm; gate oxide material - SiO ₂ ; resistivity of substrate - 1-10 Ohm.cm; metallization - Chromium/Gold-Palladium 2/50 nm; graphene field-effect mobility - >1000 cm ² /V.s; encapsulation - 50 nm Al ₂ O ₃ + 100 nm Si3N4; Dirac point (back gating) - <50 V; Dirac point (liquid gating) - <1 V; minimum working devices - >75 %; maximum gate-source voltage - \pm 50 V; maximum temperature rating - 150 °C; maximum drain-source current density - 107A.cm-2	Suited for photo / magnetic / biosensing applications





	Product	Main characteristics	Applications
`	Suspended graphene on TEM grids	Monolayer graphene, produced by chemical vapor deposition and transferred onto a Quantifoil TEM grid; suspended over 2 µm holes; transparency - > 97%; coverage - > 97%; FET electron mobility - 2000 cm ² /V.s; Hall electron mobility on SiO ₂ /Si - 2000-3500 cm ² /V.s; grain size - up to 20 µm; TEM grid substrate diameter - 3 mm; TEM grid substrate coating - gold	Suited for research, polymer composites, batteries, biomedical applications, solar cells, supercapacitors, support for metallic catalysts, low permeability materials, biosensors

Graphene foundry



Founded: 2005 Website: https://www.directa-plus.com Headquarters: Lomazzo, Italy Contact: info@directa-plus.com



Overview

Directa Plus is an Italian producer and supplier of graphene and graphene-enhanced products for consumer and industrial markets. The company primarily caters for the following markets in which it has a strong technological lead:

- environmental
- textiles
- composites
- elastomers

The company's IP portfolio contains a suite of patents across global jurisdictions: 27 granted and a further 20 pending approval.

letrics	Product type:	Powders	Production capacity:	30 tonnes/annum
Key M	Production methods:	Thermal expansion followed by exfoliation	Applications:	environment; textiles; elastomers; composite materials; golf balls; footwear





Between December 2018 and January 2019 the company raised US\$ 3.73 million (approximated) (gross) through the issuance of shares.

Shareholder	% held
Nant Capital/ Patrick Soon-Shiong	18.95
Dompè Group	13.55
Unicorn Asset Management	9.39
Dr. Jean Marc Droulers / Finanziaria Le Perray *	8.01
Galbiga Immobiliare S.r.l.**	6.75
Ruffer	4.34
Schroders Investment Management	3.91

* Finanziaria Le Perry S.p.A. is a company owned and controlled by Dr. Jean Marc Droulers.

** Galbiga Immobiliare S.r.I. is a company owned and controlled by Giulio Cesareo, the CEO of Directa Plus.





	Product	Description	Main characteristics
rbent	GRAFYSORBER®	Eco-friendly graphene-based material for the removal of oil and hydrocarbons	Features fast adsorption kinetics and recovery of adsorbed hydrocarbons and re-use of the material
Abso	GrapheneBlackTM 3X	Few-layer graphene platelets with the average thickness of 6-10 layers	For use in thermoplastics, thermosets, inks, coatings, and rubbers
S	G+® Printed Textiles	A graphene nanoplatelets-based compound	Enhanced thermal and electrical conductivity, bacteriostatic effect and anti-frictional properties for sport/citywear, technical textiles and protective wear, footwear, home textiles
Textiles	G+® Membranes	A wide range of graphene-enhanced membranes	Enhanced thermal and electrical conductivity, bacteriostatic effect, data transmission functionality, and varying degree of breathability and waterproofness for sportswear, workwear, footwear, home textiles, wearable technology applications





	Product	Main characteristics
ners	G+® Consumer	Graphene platelets enriched elastomer with improved rolling resistance ang grip, elastic modulus, and heat dissipation for on/off road, MTB, e-bike tyres
Elaston	G+® Industrial	Easy-to- process, graphene platelets enriched elastomer with improved barrier, tribological, thermal properties for membranes, hoses, o-rings
S	G+® Asphalt	A graphene nanoplatelets-upgraded modifier with improved physical-mechanical properties for road surfaces; increases the product lifetimes to up 2.5 times
Composite	G+® Extrusion Molding	A wide range of graphene-enhanced masterbatches tailored for the extrusion moulding process. Products feature bacteriostatic effect, lower deformation, better heat dissipation and UV resistance, and improved barrier properties against gas and solvents
U	G+® Injection Molding	A wide range of graphene-enhanced masterbatches tailored for the injection molding process. Products feature improved mechanical properties





As highlighted in the company's Interim Report 2019 released in September 2019:

- **Environmental:** Directa Plus made a strategic decision to develop a full decontamination service not just a product for international oil and gas markets
- **Textiles:** Directa Plus signed an exclusive agreement with Loro Piana for the commercialisation of luxurious Loro Piana fabrics and garments enriched by the company's G+ technology; the contract value contract has a minimum value more than US\$ 850k.
- The company also signed an exclusive agreement with Alfredo Grassi S.p.A., a manufacturer of workwear, to broaden existing collaboration in the development of graphene enhanced workwear and expand into the military outerwear market in Italy, part of Europe and North Africa
- There is a continued evaluation of potential new collaborations to gain increased market presence for the company's innovative denim technology based on Planar Thermal Circuit
- **Composites and elastomers:** In partnership with Iterchimica, an Italian road construction company, Directa Plus successfully completed a first commercial test of an asphalt concrete
- The company revealed plans of further testing with Ecopave on road and airport highways in Italy, UK, USA, and Oman.

References:

- 1. https://graphene-plus.com
- 2. <u>https://89099cef-be50-4f0c-bbfb-54ae33720ac5.filesusr.com/ugd/1f30fc_87dad5c7ccf249c5a4101b9df437d22e.pdf</u>
- 3. https://89099cef-be50-4f0c-bbfb-54ae33720ac5.filesusr.com/ugd/1f30fc_d493f7ab216e4771a4fe635b205495fd.pdf
- 4. https://www.directa-plus.com/environment-1
- 5. https://www.directa-plus.com/textile-1



Company: Graphene NanoChem Website: Link Headquarters: Kuala Lumpur, Malaysia Contact: Link



Overview

Graphene Nanochem PLC, founded in 2006, is a Malaysian technology company that designs, formulates, manufactures and markets a range of intermediate and performance chemicals as well as nanomaterials. It operates two commercial platforms:

- Advanced Chemicals (renewable chemical products for the oil and gas industry)
- Advanced Materials (graphene production and application development)

Graphene Nanochem owns two manufacturing hubs in Malaysia, one of which houses both Advanced Chemicals and Advanced Materials Facilities, and operates two production lines. The company focuses on the development of graphene-enhanced solutions instead of volume manufacturing.

etrics	Product type:	N/A	Production capacity:	N/A
Key M	Production methods:	chemical synthesis	Applications:	Industrial fluids; polymer and rubber composites; inks

Product Overview



Product	Grades	Main characteristics
Nanofluids	PlatDrillTM	High performance drilling fluids from renewable sources and enhanced by graphene nanomaterials with improved biodegradability and low toxicity attributes; for oil and gas industry
Polymer and rubber nanocomposites	PlatSperseTM	A unique, cost-effective method for a one-step graphene exfoliation and dispersion within a variety of water-based solutions and polymeric materials; the company is currently developing a graphene-enhanced ultra lightweight proppant for use in shale oil and gas drilling and various formulation for graphene-rubber composites
Conductive inks	N/A	Currently developing graphene-based ink for the printed electronics industry

ZEN Graphene Solutions

Founded: 2008 Website: https://www.zengraphene.com Headquarters: Ontario, Canada Contact: info@zengraphene.com



Overview

ZEN Graphene Solutions is an emerging developer of graphene-based nanomaterial products and applications. Owing to the partnership with Constance Lake First Nation, the company has secured access to Albany Graphite Deposit containing 968 kilotonnes of graphitic carbon, which easily converts to high-value graphene. The company actively collaborates with industrial end-users and academic graphene research institutions, such as the University of Toronto, and the University of British Columbia. Its current research and development effort focuses on:

- Production of graphene and graphene-based products
- Development of graphene for coating, energy storage, polymer composite, and membrane applications

etrics	Product type:	Powders	Production capacity:	N/A
Key M	Production methods:	Exfoliation (mechanical; chemical; electrochemical)	Applications:	Energy storage; coatings; membranes; polymer composites





At the end of 2019, ZEN Graphene Solutions announced that it had raised \$1.21 million (gross) through the private placement of flow-through common shares.

The company also reported that prof. Aicheng Chen and his team at the University of Guelph, the collaborators, had been awarded a \$310,000, 3-year NSERC CRD grant to continue developing an environmentally-friendly and commercially scalable electrochemical process to produce graphene oxide and graphene quantum nanodots. [Source]

Product Overview



Product	Grades	
Graphene	Albany PureTM	
Quatum graphene dots	Currently being developed	
(Reduced) graphene oxide	ZEN GO-EC Reduced graphene oxide is currently being developed	

	Main characteristics
ZEN GO-EC	Powder or aqueous dispersion; produced from Albany PureTM few-layered graphene sheets with the average sizes between 1-3 micrometers; oxygen content - 32-35%; batch size (aqueous dispersion) - 25ml, concentration - 4mg/ml





Graphene production scale-up (26 Mar 2020)

The company has commenced scale-up and engineering studies on processes for the production of Albany Pure[™] graphene products at its research and development facility in Guelph, Ontario in an attempt to meet the anticipated demand. ZEN will be working with leading university researchers to help facilitate the graphene oxide process scale-up and develop and test custom functionalized graphene formulations as per industrial collaborators requirements.

Launch of graphene products sales (02 Mar 2020)

The company has launched graphene products sales on its website in the quest to broaden its product portfolio, which includes graphene quantum dots, graphene oxide, reduced graphene oxide, and other graphene-based products.

Corporate update (20 Dec 2019)

The company has raised \$1.21 million in flow-through common company shares and will use the funds to finance the 2020 environmental baseline field program and community engagement work on the company's Albany graphite project. The offering consisted of the issuance of 3.025 million flow-through common shares at a price of 40 cents per flow-through common share.

References:

^{1.} https://www.zengraphene.com/wp-content/uploads/2020/03/ZEN-Graphene-Corporate-Presentation-March-2020.pdf

^{2. &}lt;u>https://www.zengraphene.com/wp-content/uploads/2020/02/ZEN-Graphene-Info-Fact-Sheet-March-2020.pdf</u>

^{3. &}lt;u>https://shop.zengraphene.com/collections/graphene-oxide/products/zen-go-ec#specs</u>

^{4. &}lt;u>https://www.zengraphene.com/zen-graphene-solutions-scaling-up-graphene-production/</u>

^{5. &}lt;u>https://www.zengraphene.com/zen-graphene-solutions-announces-the-launch-of-graphene-product-sales/</u>

Archer Exploration

Founded: 2007 Website: <u>https://archerx.com.au</u> Headquarters: Wayville, Australia Contact: <u>hello@archerx.com.au</u>



Overview

Archer Exploration Ltd. is an Australian materials technology company that develops and explores graphite, copper, cobalt, manganese, tin and tungsten resources for the applications in quantum technology, human health and reliable energy. Its business priorities are:

- · Commercialization of the 12CQ quantum computing chips
- Intellectual protection of printable graphene biosensors
- Integration of the Campoona Graphite Project (size 1.65 megatones)
- Monetization of its mineral exploration tenements

etrics	Product type:	N/A	Production capacity:	N/A
Key M	Production methods:	Electronic exfoliation	Applications:	Currently being developed; the focus is on batteries





News (as highlighted in the company's presentation released in January 2020)

In quantum technology:

- Obtained exclusive licence to quantum technology IP
- · Signed Access agreements to access chip building foundry
- · Assembled first components of 12CQ qubit processor chip
- Began second-stage development involving quantum measurements
- In human Health
- Prepared and tested high quality graphene inks for printed biosensing technologies
- Lodged a provisional patent lodged for graphene-ink biosensing technology
- Printed human antibodies on graphene biosensor components
- Built a first-phase prototype graphene biosensor platform
- Reliable Energy
- · Produced state-of-art, full-cell Li-ion batteries from Campoona graphite
- Produced spherical graphite matching market requirements for Li-ion batteries from Campoona graphite
- Produced Li-ion batteries using Campoona spherical graphite

References:

- 1. https://archerx.com.au//src/uploads/2019/09/20190917_Annual-Report-2019-ASX-Release.pdf
- 2. https://archerx.com.au//src/uploads/2020/03/Archer-Presentation-for-webready-JAN2020-1.pdf



Founded: 1993 Website: https://www.cometres.com.au Headquarters: Subiaco, Australia Contact: comet@cometres.com.au



Overview

Comet Resources Ltd. is an Australian mineral exploration and R&D company. The company owns a 15.6 megatonnes graphitic project (Springdale Project) and has the 2375ha exploration license of copper project (Barraba Project). Following the successful recovery of graphene from the Springdale Project in 2017, the company has undertaken the graphene research and application development.

letrics	Product type:	N/A	Production capacity:	N/A
Key M	Production methods:	electronic exfoliation	Applications:	Currently being developed; the focus is on batteries





In January 2020 the company received an R&D grant of nearly US\$ 310k (approximated) from the Australian government. It also raised more than US\$ 400k through the issuance of shares. The company has plans to raise another US\$ 1M+ to fund the Baraba Copper Project acquisition.





As highlighted in the quarterly activities report released on 29th of April 2020:

- The company has announced the completion of acquisition of the Barraba Copper Project and beginning of the initial physical exploration program as part of the strategy to grow business in the battery sector
- The company continued the metallurgical test work on the Springfield Graphite Project and assessment of the market potential; Results reported in July 2020 showed that the project achieved a total carbon (TC) grade of 96.9% with a recovery of 92.5% TC in the sample.
- The receipt of a R&D grant payment of nearly US\$ 300k.

References:

- 1. https://www.cometres.com.au/sites/default/files/asx-announcements/6976931.pdf
- 2. <u>https://www.proactiveinvestors.co.uk/companies/news/924211/comet-resources-achieves-strong-graphite-grades-and-re</u> <u>coveries-in-springdale-project-tests-924211.html</u>

2D Carbon Graphene Material

Company: 2D Carbon Graphene Material Website: <u>http://www.cz2dcarbon.com/en/</u> Headquarters: Jiangsu, China Contact: cz2d@2dcarbon.com.cn



Overview

2D Carbon Graphene Material Co., Ltd., established in 2011, is a Chinese, award-winning producer and retailer of graphene and graphene-based products. The company specialises in manufacturing and research and development of large area graphene films and touch modules.

Products include:

- Graphene pressure sensors
- Graphene touch sensors
- Graphene heating films
- Graphene membranes
- Other graphene products

etrics	Product type:	Graphene films	Production capacity:	200,000 m² per annum
Key M	Production methods:	Chemical vapor deposition	Applications:	Touch controls for industrial/home appliances; smart wearables; medical devices



NEXT STEPS

PRESCOUTER 95

Potential Next Steps

Report	Topic - What is the current status on graphene production and research?	
Intelligence Brief 1	Companies producing graphene and graphene-based products commercially (this Intelligence Brief)	
Intelligence Brief 2	Start-ups and academics involved in graphene production and research (for example MIT's new roll-to-roll production method that promises pristine graphene)	
Intelligence Brief 3	IP landscape on graphene production and research	
Intelligence Brief 4	Deep dive into key companies/researchers to get data not available in the public domain (for example, production capacities were missing and prices of products)	
Data Analysis and Final Recommendations for Recap Report		



SOME POSSIBILITIES THAT PRESCOUTER CAN OFFER FOR CONTINUATION OF OUR RELATIONSHIP

	TECHNOLOGY	TECHNOLOGY & PATENT	MARKET RESEARCH
	ROADMAPPING	LANDSCAPING	& ANALYSIS
TRENDS MAPPING	REVIEW BEST PRACTICES	PATENT COMMERCIALIZATION STRATEGY	M DATA ANALYSIS & RECOMMENDATIONS
ACQUIRE NON-PUBLIC	SUPPLIER OUTREACH	CONSULT WITH INDUSTRY	INTERVIEWING
	& ANALYSIS	SUBJECT MATTER EXPERTS	COMPANIES & EXPERTS

WE CAN ALSO DO THE FOLLOWING

- ✓ CONFERENCE SUPPORT: Attend conferences of interest on your behalf.
- **WRITING ARTICLES:** Write technical or more public facing articles on your behalf.
- ✓ WORKING WITH A CONTRACT RESEARCH ORGANIZATION: Engage with a CRO to build a prototype, test equipment or any other related research service.

For any requests, we welcome your additional questions and custom building a solution for you.



The Technology Readiness Level (TRL) Scale is an industry standardized metric by which PreScouter evaluates technologies for each client. Based on the constraints on the innovation challenge, PreScouter assigns a TRL number to each identified academic, company or patent.

This process allows each solution to be easily identified for commercialization potential.

Higher number TRL's do not always equate to the best technology – for example, most late stage academic technology is best suited for optimization and integration, but would have a TRL between 2-4.





Marija Jović

PreScouter

Professional Summary:

Marija has been a Project Architect with PreScouter since January 2015. She finished her Master's degree in Chemical Engineering from Belgrade University and completed her PhD in Organometallic Chemistry and Catalysis at the Swiss Federal Institute of Technology (ETH Zurich). Marija's academic research was focused on understanding reaction mechanisms in order to rationally design catalysts for polymerization and metathesis reactions. Prior to her PhD, Marija worked in chemical industry on synthesis of new textile dyes.

Research Background:

Polymer Chemistry and Engineering, Materials Science, Catalysis, Innovative Technologies





Delft University of Technology

Professional Summary:

Karolis boasts 8 years of academic and industrial experience in polymer research. In 2016, he obtained a PhD from Delft University of Technology, the Netherlands, wherein he developed a method for producing alginate biopolymer-graphene nanocomposites with a tunable orientation of graphene sheets arising out of the formulation and published the findings in 3 peer-reviewed international scientific journals. Most recently, he successfully completed the knowledge transfer partnership project between the academic and industrial partners, which, among other things, greatly improved business' engineering capability. Karolis maintains deep interest in polymeric materials and researches and analyses the latest developments in the materials industry.



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