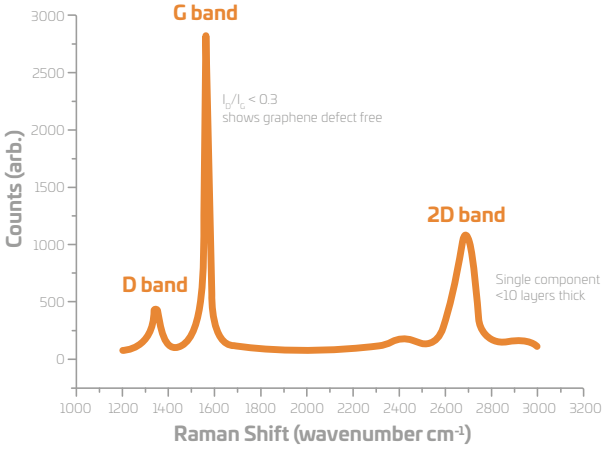
Nanene™

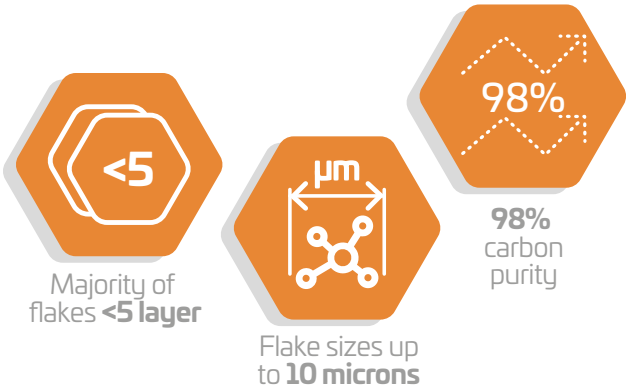
High Purity, Low Defect Graphene

> *"Establishing global benchmarks in few-layer graphene production is important as disruptive technology works best when standards have clarity"*
>
> **Neill Ricketts, CEO**

Nanene™ offers limitless opportunities

A high quality graphene powder, Nanene™ comprises mono, bi and few-layer graphene flakes. The high graphene purity and low defect ratio establish Nanene™ as an outstanding commercially available product that enables true leverage of graphene's unique properties.





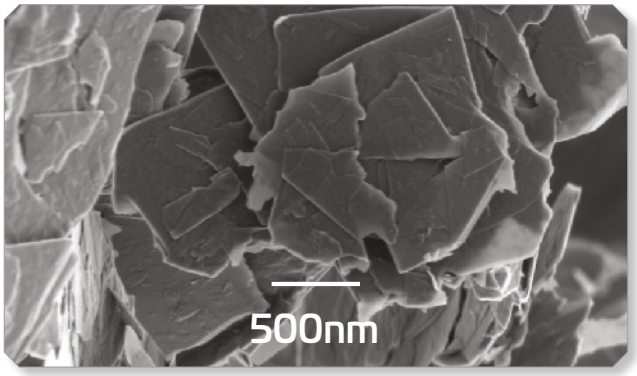
Majority of flakes **<5 layer**

Flake sizes up to **10 microns**

98% carbon purity

Versarien's® patented production processes leave graphene flakes relatively pristine and undamaged. With an impressive D/G peak ratio of ~0.3*, studies confirm Nanene™ has a high proportion of few-layer graphene flakes, including some mono and bi-layer, with 90% of Nanene's™ particles being less than 3.5 nanometres / ten layers.

*The lower this number the better, with alternative products having a D/G peak ratio of up to ~2.0.



SEM [1kV] image of bulk Nanene™ showing large flakes

Versarien® has four graphene facilities in the UK.

Versarien® uses two separate patented and scalable manufacturing processes to produce 2D materials.

by Versarien®

What is Graphene?

First isolated in 2004 by two researchers at the University of Manchester, pure graphene is a single atom thick and is referred to as a 2D material.

It is incredibly strong (200 times stronger than steel) and has some very impressive new properties over and above it's 'parent' graphite.

Bi-layer and few-layer graphene has properties that measure in the same ranges as mono-layer graphene. As the number of layers increases these properties start to significantly reduce.

That is why we only sell powder with high proportions of few-layer flakes.

See below for graphene properties as measured in pristine mono-layer flakes:

Thermal Stability
Stable to decomposition at high temperatures

Thermal Conductivity
The perfect conductor **>5,000 W/(m•K)**

Electrical Conductivity
The **fastest & most efficient** conductor

Light Absorption
Absorbs all light frequencies **2.3% per layer**

Gas Permeability
Impermeable to gases. Prevents oxygen ingress

Chemical Stability
Inert material, so increases chemical resistance

Mechanical Strength
Tensile strength **1.30GPa** Young's Modulus **> 1TPa**

Nanene™
Versarien

Technical Specifications

Property	Measurement	Method
Layers ≤5	60%	Raman
Layers ≤10	90%	Raman
Layers >10	10%	Raman
Defect ratio	0.3AV. I_D/I_G	Raman
Lateral Dim.	<10µm	SEM

Concentration (At.%)

Carbon	Oxygen	Flourine	Sulphur	Nitrogen
98 ± 1.0	2.0 ± 1.0	0.5 ± 0.5	0.5 ± 0.5	0.3 ± 0.3

Why is Nanene™ so Special?

We produce graphene powder with significant few-layer flakes, including mono and bi-layer.

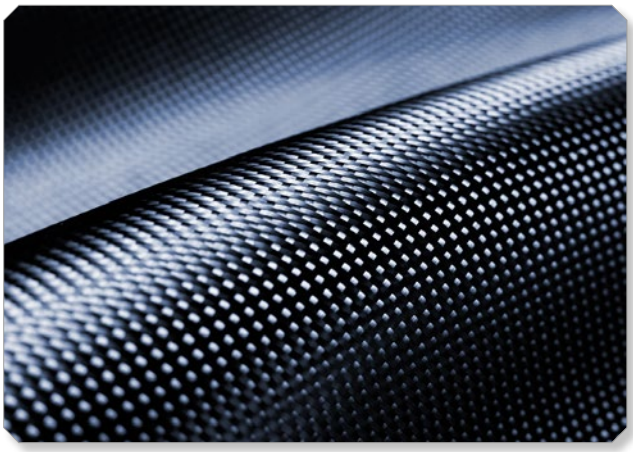
We then take that powder and put it through further processing in order to isolate only the very best quality graphene. This is Nanene™. With 60% ≤5 layers and 90% ≤10 layers and 98% purity, Nanene™ is an outstanding graphene powder and is available today for commercial supply.

Potential Applications:

Graphene has the potential to revolutionise a wide range of industries.

Being electrically conductive, thermally conductive and a highly effective mechanical reinforcer there are numerous potential applications for graphene such as:

Composites · Energy · Biomedical · Membranes · Coatings · Sensors · Electronics



Graphene adds strength and flexibility to composite materials

Graphene is being used to develop biomedical sensors

by Versarien®

Graphene Powders: Solutions for Diverse Graphene Applications

We use two different patented processes to produce our graphene and are partnered with both the University of Manchester and the University of Cambridge.

GNP-HP

Versarien

Technical Specifications

Property	Measurement	Method
Layers ≤5	18%	Raman
Layers ≤10	73%	Raman
Layers 10-100	27%	Raman
Defect ratio	0.3AV. I_D/I_G	Raman
Lateral Dim.	<26.5µm	SEM

Concentration (At.%)

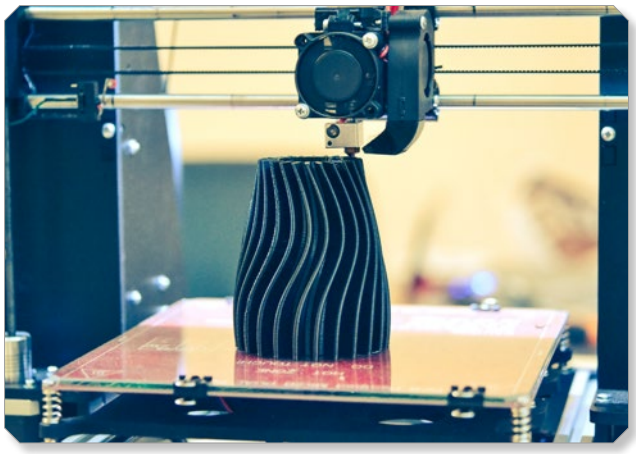
Carbon	Oxygen	Flourine	Sulphur	Nitrogen
96 ± 3.0	3.0 ± 2.0	1.0 ± 1.0	1.0 ± 1.0	0.3 ± 0.3

Majority of flakes **<10 layer**

Particle sizes up to **26.5 microns**

Very Low defect ratio

GNP-HP is a few-layer graphene powder with large lateral dimensions. With a defect ratio to match Nanene™, GNP-HP is suitable for a wide range of applications and has shown significant improvements in tensile strength, Young's modulus, uniform elongation and elongation at break.



Graphene is being used in 3D printing applications

Graphene Oxide Powders: Oxygen Bonding Benefits

In addition to our high quality, low defect graphene powders, we also supply graphene oxide and reduced graphene oxide. With a higher defect ratio, these products are suitable for different applications where the high proportion of oxygen would be beneficial.

GO

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Technical Specifications

Property	Measurement	Method
Layers	Majority ≤2	AFM
Defect Ratio	>1 AV. I_D/I_G	Raman
Lateral Dim.	<4 µm	SEM/AFM
Colour	Brown	

Concentration (At.%)

Carbon	Oxygen	Sulphur	Nitrogen	Mn
60 ± 5.0	33 ± 5.0	2.5 ± 2.5	1.5 ± 1.5	1.5 ± 1.5

Majority **<2 layer** flakes

Lateral dimensions up to **4 microns**

60% Carbon 33% Oxygen

RGO

Versarien

Technical Specifications

Property	Measurement	Method
Layers	<100	AFM
Defect Ratio	1.5 AV. I_D/I_G	Raman
Lateral Dim.	<20 µm	SEM/AFM
Colour	Black	

Concentration (At.%)

Carbon	Oxygen	Sulphur	Nitrogen	Mn
85 ± 7.5	12 ± 7.5	1.5 ± 1.5	2.5 ± 2.5	1.5 ± 1.5

<100 layer flakes

Lateral dimensions up to **20 microns**

85% Carbon 12% Oxygen

Potential Applications:

Li-ion batteries and fuel cells, battery electrodes, solar PV cells, electrically conductive inks, thermally conductive films and coatings, thermal interface materials, lightweight composites, concrete, metal-matrix composites, corrosion protection, improved barrier properties, permeation and mechanical performance.

by Versarien®

GRAPHINKS | Conductive Ink Technology

Our own graphene inks are produced via a patented micro-fluidisation process. Printable conductive inks for flexible electronics can be both cheaper and more flexible that traditional circuit board solutions. We have two different inks suitable for different deposition methods. Both are environmentally friendly, non-toxic, aqueous and can be stored at room temperature (20°). We also formulate graphene inks for specific customer requirements.

		GRAPHINK 1	GRAPHINK 2
Typical Ink Characteristics	Solvent	Water	Water
	Viscosity (@ 100 s-1)	3-4cP	~600cP
	Total solids content	~0.1 wt%	10.3 wt%
Typical graphene Characteristics	Flake type	Few-layer graphene	Graphene plus graphite nanoplatelets
	Lateral size	80-500µm	1000 ± 500µm
	Thickness	Few-layer, <3 µm	~10 ± 5µm
	Graphene Content	0.2-0.5 mg/mL	100 mg/mL
Typical Film Properties	Deposition method	Ink Jet Printing/ Vacuum Filtration/ Meyer Bar Coating	Flexo/ Gravure/ Screen Printing/ Blade/ Meyer Bar Coating
	Drying conditions	100°C for 10 min	
	Sheet resistance @ thickness	~4 kΩ/□@80nm, 30 kΩ/□@2µm	~10 Ω/□@25µm
	Transparent films	Yes	No
	Transparent substrates	Glass, Paper, Plastics	

Graphene Ink Closeup - Photo Credit toJames Macleod

Versarien® Tomorrow's Materials Available Today

Versarien® PLC is at the cutting edge of 2D material development. Founded in 2010, Versarien® is a specialist materials producer that delivers engineering advantage through innovation to a broad variety of industry sectors.
With over 100 staff in five different locations across the United Kingdom, Versarien® is leading 2D materials development and manufacturing, with patented processes scaled up for commercial supply. In addition, research collaborations with leading institutions and strategic commercial partnerships are enabling this disruptive technology to become a reality.

Want to know more? Get in touch today
www.versarien.com
info@versarien.com
+44 (0) 1242 269 122

We'd love to talk to you about research collaboration, partnerships and commercial 2D material supply.

Our current partners: MANCHESTER 1824 The University of Manchester National Graphene Institute; Graphene-info; The Graphene Council Research, Development and Application