Nixene Publishing

Clarity from Complexity™

Trends in Graphene Applications

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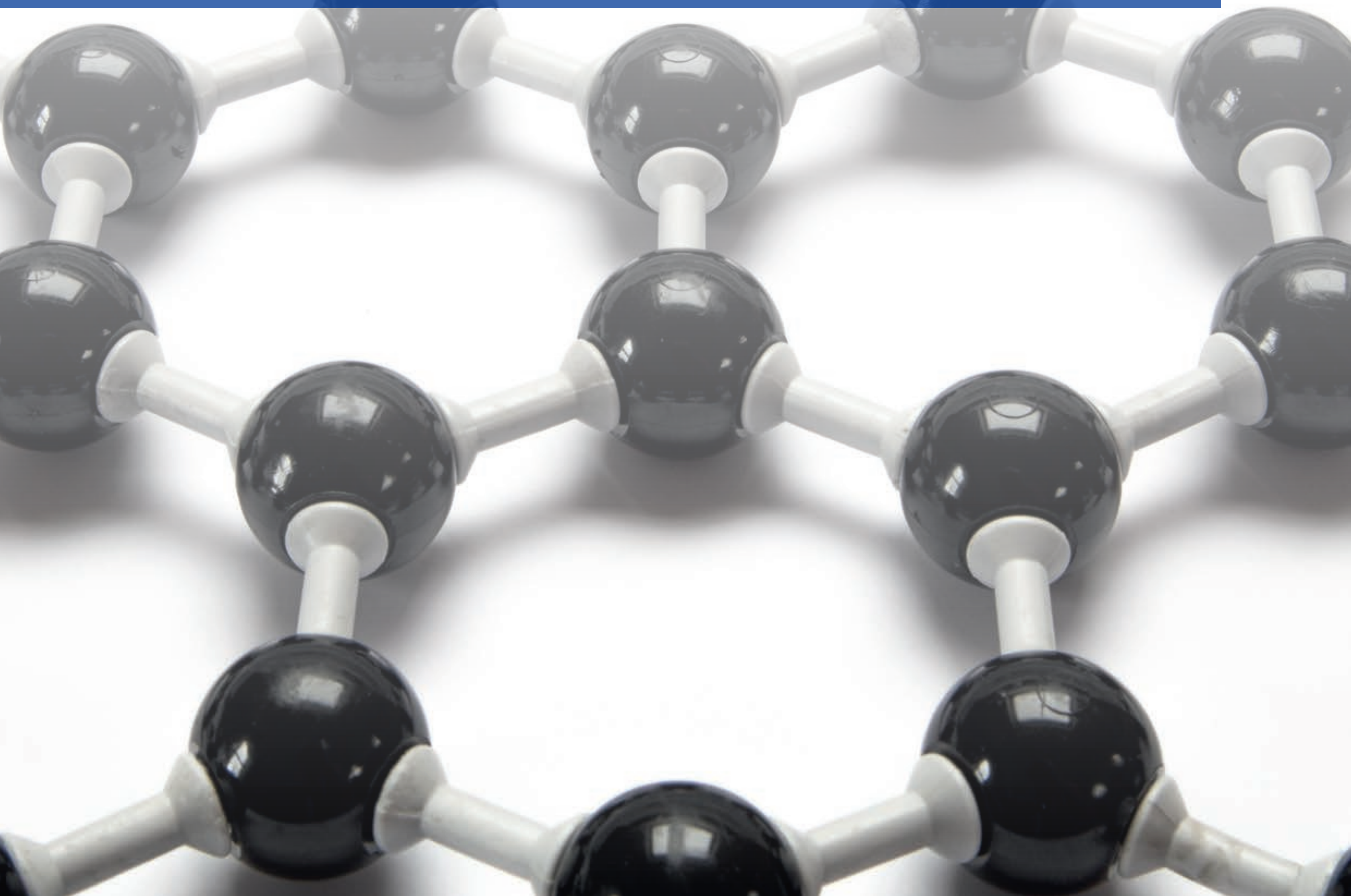

Contents

Introduction

This short paper provides an analysis of graphene related applications that have been reported on in the Nixene Journal over a 5-year period between October 2017 and December 2022. It illustrates the top 40 applications and trends over this time period.

Background

The Nixene Journal is published monthly summarising technology and market developments in the world of Graphene and 2D. We use Google alerts and referrals from our extensive network to identify potential articles. These articles are then 'curated' by Adrian Nixon to create 40-50 articles a month for each Journal.

We have tried to standardise the language that we use to describe market sectors, applications, and product types. We use this to create a consistency of approach in terminology for both technology and market developments. Each article in the Journal has a navigator table highlighting the content in terms of market sector, application and product type, see Figure 1. These 'navigator headings' are intended to be a quick and easy guide to enable busy people to categorise and identify the content of an article.

Our navigator headings are constantly developing over time as the graphene and 2D field evolves. The current navigator headings can be found in Appendix 1.

One article to a page with market keywords

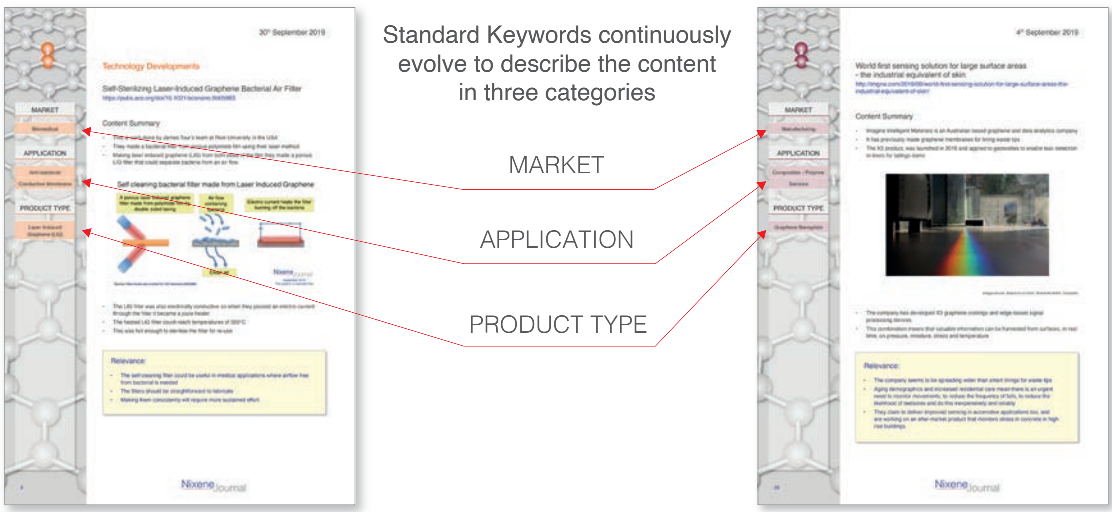

Figure 1: Navigator Headings.

Word Cloud Analysis

We reviewed all the articles published since we started the Journal in October 2017 - up to and including December 2022 (Volume 6, Issue 12). We compared these articles against the standardised nomenclature that we use (see Appendix 1). The purpose being to identify the emerging trends in graphene applications, to identify what applications are being worked on and reported the most.

We created a Word Cloud to create a visual representation identifying the frequency or importance of each application referenced in the Journal - see Figure 2.

It is quite clear that Polymer Composites is by far and away the greatest area of activity that is both researched and reported on. This is unsurprising, it has featured as the largest area of activity every time we have undertaken this type of analysis (May 2020, November 2020, January 2021, July 2021).

Figure 2: Frequency of applications referenced in the Nixene Journal, illustrating the dominance of polymer composite applications.

Polymer Composites are so dominant in our Word Cloud that other areas of activity have been obscured. Next, we removed the dominant application and reset the Word Cloud. Figure 3 illustrates these other areas of application and clearly shows the range of other applications that emerged – Sensors, Coatings, Batteries, Concrete, Anti-Corrosion and Heat-management. Again, this follows a similar pattern to previous analyses, with Sensors, Coatings and Batteries demonstrating slightly increased dominance.

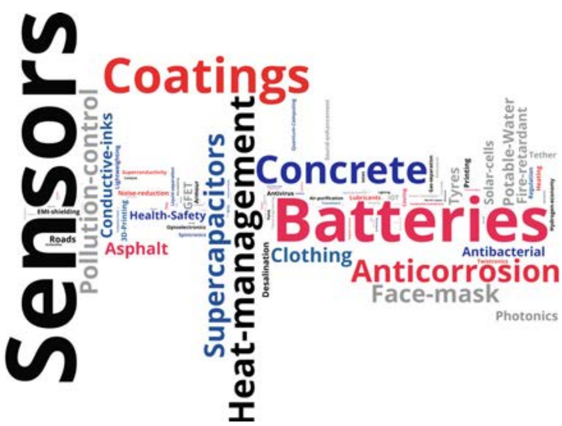

Figure 3: Applications excluding Polymer Composites.

Word Cloud Analysis

Finally, we removed Sensors and all applications with less than 5 references to try and reduce the 'noise' in order to clearly see those applications that might be termed 'second rank'. This illustrates the true breadth and scope of graphene applications. Supercapacitors, Face-masks (perhaps unsurprisingly given the recent pandemic), Heat-management, Pollution Control and Anti-corrosion all begin to feature and represent the next 'tier' of graphene related applications where there is a significant degree of activity.

Figure 4: 'second rank' graphene applications

Applications referenced more than 10 times

We ranked the number of applications referenced 10 times or more in the Nixene Journal - see Figure 4.

As in previous analyses Polymer Composites (255 references in July 2021, 39% increase), along with Sensors (151 references previously, 32% change), Batteries (increase of 51) and Coatings (increase of 20) are the most frequently referenced graphene applications. In percentage terms, Batteries have demonstrated the greatest change – nearly a 70% increase.

In terms of ranking, the predominant applications have only changed slightly since we last conducted this analysis. Battery applications have overtaken Coatings in the ranking. Concrete & Cement (79, 55% increase) has overtaken Heat Management (72 references).

These increases are demonstrating not only the strength, but also the breadth of activity that is now taking place in the world of graphene and 2D applications. If this can be regarded as a proxy for market pull then we are beginning to see the development of significant market driven activity.

Rank	Application	Nos. of References
1	Composites - polymer	317
2	Sensors	199
3	Batteries	124
4	Coatings	99
5	Composites - concrete and cement	79
6	Heat management	72
7	Anti-corrosion	63

Rank	Application	Nos. of References
8	Supercapacitors	57
9	Face mask	50
9	Pollution control	50
10	Clothing	40
11	Composites - asphalt	34
12	Conductive inks	32
13	Potable Water	31
14	Tyres / Tires	29
15	Fire retardant	28
=16	Anti-bacterial	26
=16	Photonics	26
=16	Solar cells	26
17	GFET Sensors	24
18	Health & Safety	23
19	Desalination	18
19	Roads	18
20	Tether	17
=21	3D Printing	15
=21	Printing	15
=22	EMI shielding	13
=22	Heating	13
=22	Internet of Things (IOT)	13
=22	Noise reduction	13
=23	Anti-virus	12
=23	Armour	12
=23	Lubricants	12
=23	Lightweighting	12
=23	Regulations /REACH	12
=23	Sound enhancement	12
=24	Hydrogen economy	11
=24	Twistronics	11

Trends Over Time

We examined the trends in graphene applications over time. This is mainly a look at which applications started 'moving,' giving us an indication of the direction of travel into the future.

Figure 5 illustrates the top 10 rankings and shows three clear 'front-runners' out of the top ten graphene applications that we have referenced in the Nixene Journal:

- Polymer composites with over 300 references more than double the number of references since July 2021, has also seen a slight increase in trajectory since June of last year.
- Sensor applications have shown a steady increase.
- Batteries applications have shown an increase in activity over coatings since December 2021.

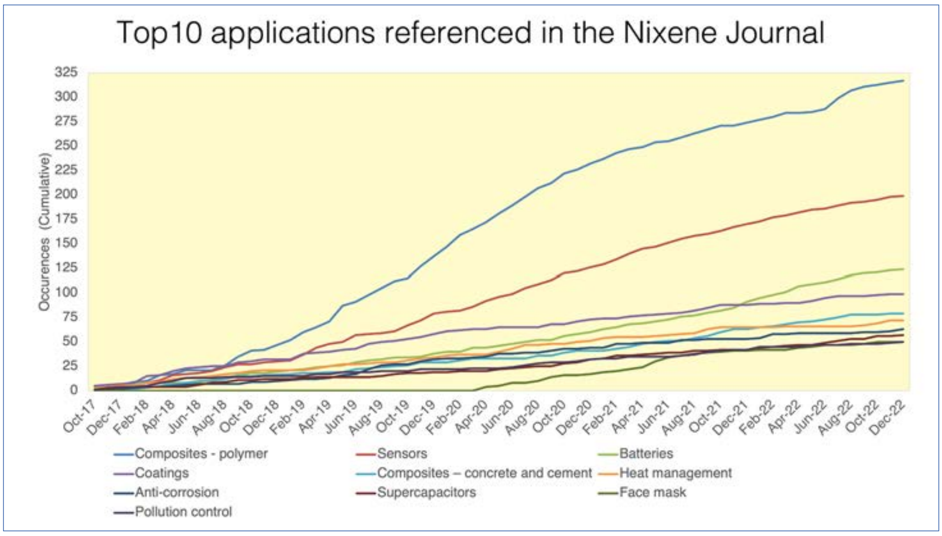

Figure 5: Top 10 Graphene applications referenced in the Nixene Journal.

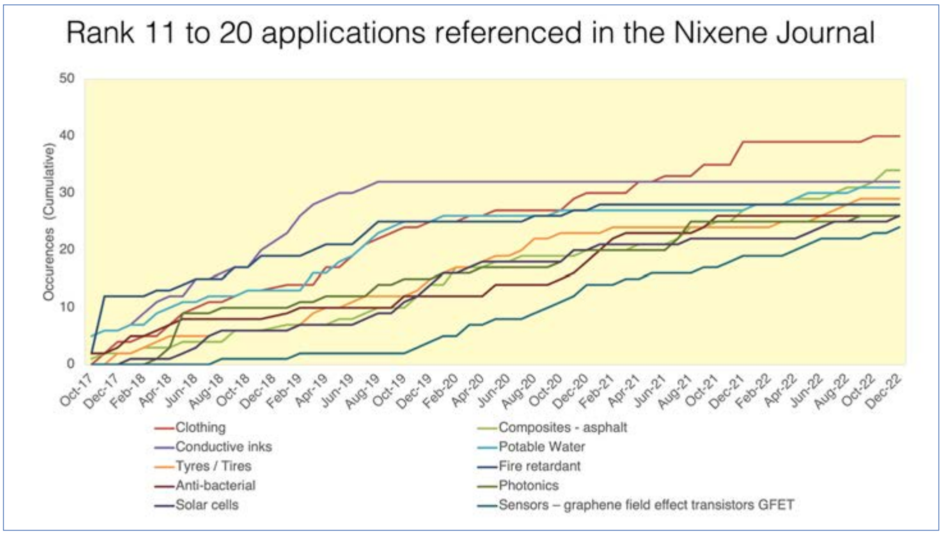

Figure 6: Graphene applications ranked 11-20 in the Nixene Journal.

Figure 6 illustrates those applications ranking 11 to 20, generally referenced up to 40 times in the Nixene Journal:

- Clothing applications for graphene have been referenced the most times and shown a steady increase only slowing down over the past 12 months.
- Although smaller numbers of references GFET Sensors with steadily increasing numbers of applications in evidence over the past 3 years – commencing October 2019. This is most probably a consequence of the recent pandemic and the need for COVID detection.
- Conductive inks after initial activity have provided few or no additional references over the past 3 years.

Figure 7 illustrates applications ranked 21 to 30. Generally referenced up to 25 times.

Low numbers make identifying trends difficult but:

- Health & Safety applications have shown a steady and interesting increase.
- Both Tethers and Heating have shown the recent increases in the number of applications.

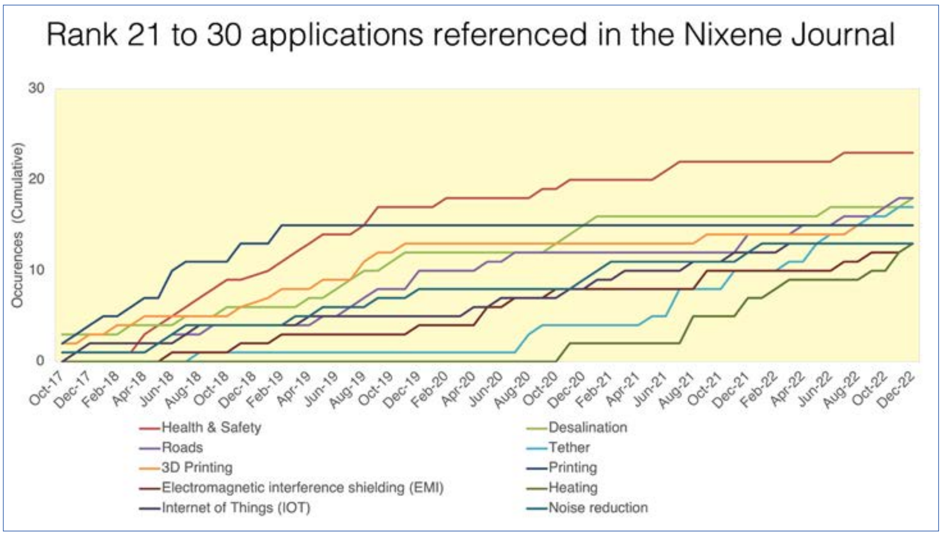

Figure 7: Application ranked 21 to 30.

Figure 8 illustrates the applications that we have referenced on at least 10 or more occasions. The small numbers make this graph busy. There is however one interesting trend – the emergence of the Hydrogen Economy since March 2021 as an application utilising graphene. If this trajectory continues at a similar pace, we might see considerably more activity and interest in this field.

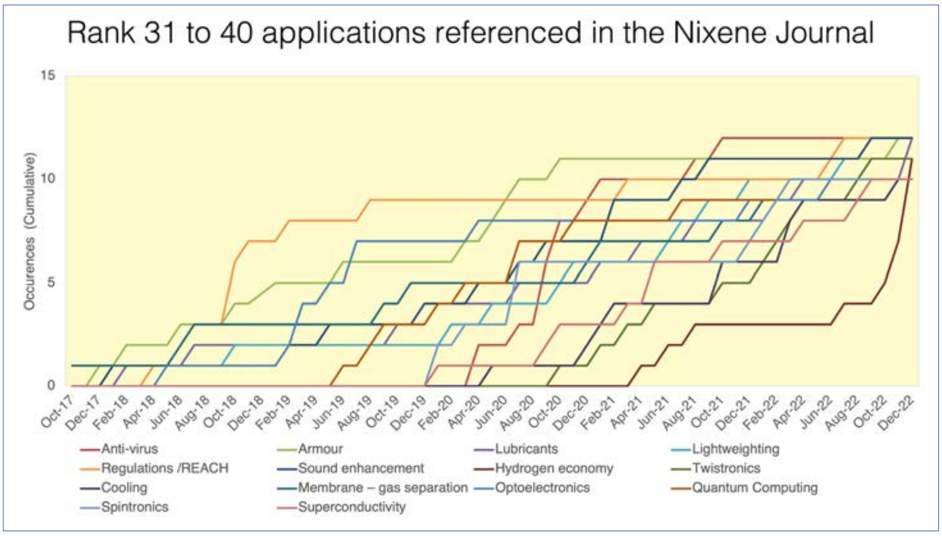

Figure 8: Next ten graphene applications.

Trends Analysis Summary

Analysing our own keyword trends between 2017 and 2022 gives us a unique insight into the way the graphene and 2D market applications are evolving. This is primary data generated by us in a consistent and systematic way as a by-product of creating the journal for you each month.

This means no one else has the unique view we can share with you.

By its very nature, this analysis looks back at the trends over time. What we can all see is where these trends are headed in the immediate future.

Our top ten data shows again that graphene nanoplate powders and dispersions are where the commercial activity is not only taking place at present but increasing. We expect this trend to continue for the foreseeable future. Other than Sensors, we are not yet seeing significant activity in applications based upon CVD graphene.

Commercial applications for graphene nanoplate powders and dispersions are now focussing on four main areas:

- Polymer composites: improving the mechanical properties of the base polymer.
- Sensors: developing cost effective and sensitive sensors for a variety of chemical, biological and physical sensing applications.
- Batteries: improve charging, increasing their energy density and managing temperature
- Coatings: Developing graphene-based coatings to enhance anti-corrosion, anti-microbial and fire retardancy.

We expect that future markets for graphene applications will expand and increasingly create a market pull, with uses in industries such as energy storage, electronics, healthcare, aerospace, automotive, and more.

Customers are increasingly understanding:

- the benefits of how to work with graphene
- the performance enhancements that can accrue from the addition of graphene
- those applications where the most benefit from graphene can be obtained.

Drilling down into the applications shows further upward trends in:

- Clothing, Asphalt, GFET sensors, Heating, Health & Safety and the Graphene Economy.

We can expect these themes to continue. This exercise in mining our accumulated data is certainly something we will repeat.

Significance:

- Markets for graphene-based applications are increasing, particularly for specific applications.
- Applications based upon graphene powders are beginning to showing greater diversification.
- This suggests that markets are becoming increasingly more sophisticated and more developed for these products.
- This is indicative of a greater market pull, rather than the technology push from graphene producers and manufacturers in the past.
- We may be approaching a tipping point in the market where performance enhancements from graphene are understood and demand in being created.

Examples of Applications in the Nixene Journal

By way of illustrating the ‘navigator headings’ and how we use this nomenclature in the Nixene Journal, the following pages show some examples of articles from recent Journals.

MARKET

Defence

Research & Development

APPLICATION

Composites - Polymer

PRODUCT TYPE

Graphene Nanoplate

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Composites

Multi-functional Composites: Lighter Tactical Helmets

https://www.linkedin.com/posts/2dmsolutions_2dm-graphene-realgrapheneworks-activity-6940155792884908032-0rJt/

https://e2-materials.com/application/multifunctional/

Content Summary

- This is work done by 2DM, the spin out company from the University of Singapore
- Plastics engineering magazine featured this helmet made by Australian- Singaporean company Smart Think
- The helmets are made of Aramid and an epoxy resin
- Adding graphene improves the V50 ballistic performance of the material by 15%

Case graphene enhanced composite helmet. Image credit: 2DM.

- This means the company can manufacture graphene enhanced helmets with a 20% weight saving for the same ballistic resistance as normal helmets
- The company is now experimenting with graphene enhanced ultra-high molecular weight polyethylene graphene composites
- One additional benefit of the graphene composite is said to be the improved recyclability of the polymer at the end of life.

Significance:

- 2D materials has been quietly working on these graphene enhanced polymers for ballistic protection since 2017
- This article shows they seem to be gaining acceptance from the security forces in Singapore and Australia

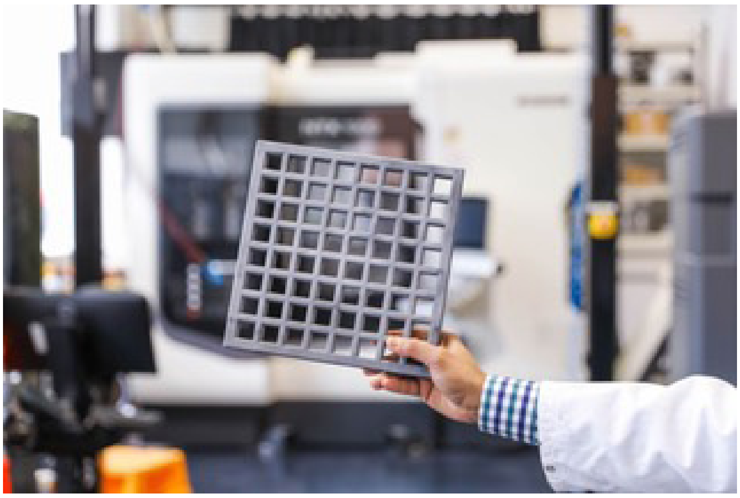
Swinburne and Sparc technologies develop self-sensing graphene enhanced carbon fibre composites

https://www.compositesworld.com/news/swinburne-sparc-technologies-researchers-to-create-graphene-enabled-smart-composites

https://www.swinburne.edu.au/news/2022/09/next-gen-materials-take-flight-with-swinburne-research/

Content Summary

- Swinburne University and Sparc Technologies announced a joint development project funded by the Australian research council (ARC)
- The ARC Linkage Grant from the Federal Government, is worth $1 million
- This supports the next generation of smart composites
- The aim is to develop embedded sensors that can report on the integrity of carbon fibre composite structures



Self-sensing graphene enhanced composite material. Image credit: Swinburne University.

- Swinburne University is providing the expertise and resources for the composites
- Sparc technologies is providing the graphene and applications expertise
- The aim is to allow technicians to monitor wind-turbine blades in remote mountain or coastal locations and detecting faults in airplane and rocket parts before they fail.

Significance:

- Swinburne University and Sparc technologies are developing connected smart structures that can be wirelessly monitored in real time
- The aim is to monitor hard-to-detect defects, enabling safer, more reliable and cheaper air and space travel
- The work is funded by the Australian government but is not complete yet.

MARKET

Research & Development

APPLICATION

Composites - Polymer

Sensors

PRODUCT TYPE

Reduced Graphene Oxide (rGO)

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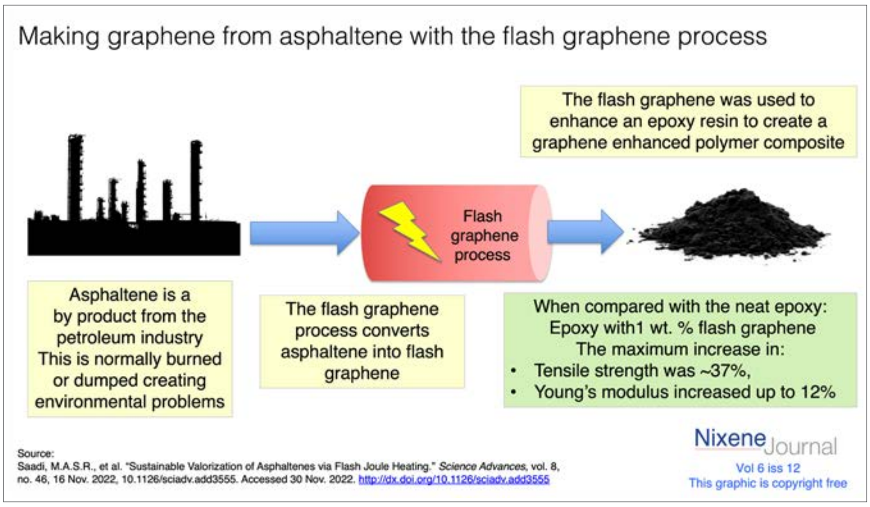
MARKET
Manufacturing
Research & Development
APPLICATION
Composites - Polymer
PRODUCT TYPE
Flash Graphene
Back to Contents

Flash graphene made from asphaltene enhances polymer composites

https://www.science.org/doi/10.1126/sciadv.add3555
DOI: 10.1126/sciadv.add3555

Content Summary

- This is work done by a team at Rice University in the USA
- The team started with asphaltenes which are a by-product from petroleum oil refining
- Asphaltenes are normally burned as fuel creating CO2 and other emissions or dumped to landfill
- The team found that the flash graphene process can convert asphaltenes into graphene (vol 4 iss 2 p.9)



- The asphaltene flash graphene (AFG) was used to enhance epoxy polymer composites
- The graphene enhanced epoxy polymer had:
  - Increased tensile strength of 37%
  - Increased Young's modulus of 12%

Significance:

- Asphaltenes are a problematic by-product of petroleum refining
- The flash graphene process works well using asphaltene as a feedstock
- The flash graphene improved the tensile strength and Young's modulus of an epoxy resin
- Again, demonstrating the ability of the flash graphene process to turn a waste product into a higher value performance additive for polymer composites.

Sensors

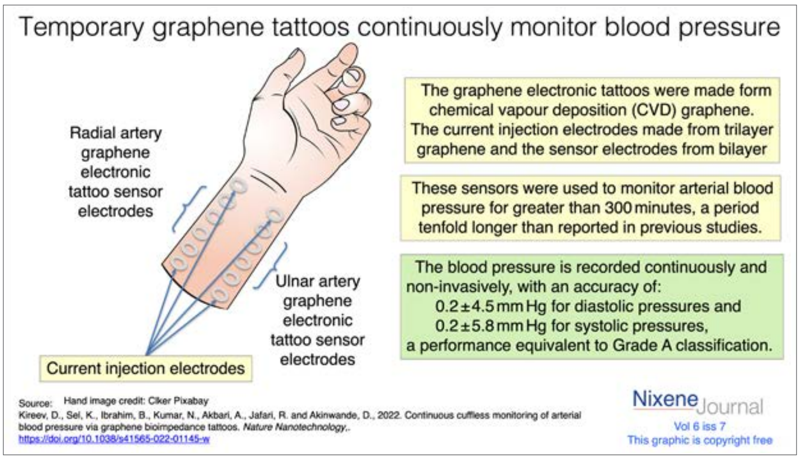
Temporary graphene tattoos could continuously monitor blood pressure

https://www.newscientist.com/article/2325029-temporary-graphene-tattoos-could-continuously-monitor-blood-pressure/

DOI: 10.1038/s41565-022-01145-w

Content Summary

- This is work done by a team at the University of Texas at Austin, USA.
- They made an array of flexible graphene sensors from CVD graphene.
- They called these graphene tattoo electrodes.
- There were two sets of six electrodes.
- The outer electrodes inject the AC current and are made from trilayer graphene.
- The inner four electrodes are two pairs of bilayer graphene for sensing.
- The sensors measure the blood pressure continuously and non-invasively,



with an accuracy of:

- 0.2±4.5 mm Hg for diastolic pressures
- 0.2±5.8 mm Hg for systolic pressures,

- This is a performance equivalent to Grade A classification.

Significance:

- This work shows that CVD graphene manufacturing technology has advanced to the point where these kinds of biosensors can be made routinely.
- CVD graphene has a much higher electrical conductivity than graphene powders.
- This means it can make much more sensitive biosensors.

MARKET

Biomedical

Research & Development

APPLICATION

Sensors

PRODUCT TYPE

CVD Graphene

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MARKET

Biomedical

Research & Development

Textiles

APPLICATION

Sensors

PRODUCT TYPE

Reduced Graphene Oxide (rGO)

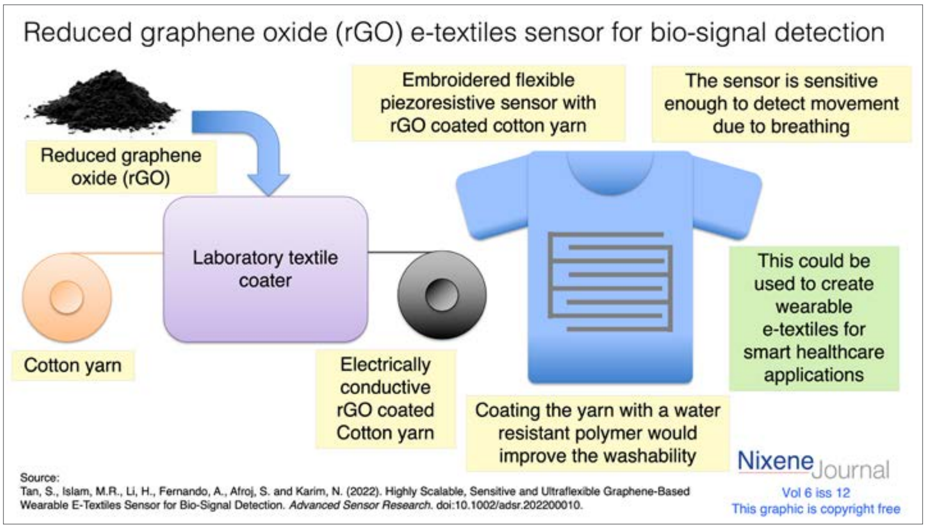
Back to Contents

Highly scalable, sensitive, and ultra-flexible graphene-based wearable e-textiles sensor for bio-signal detection

https://onlinelibrary.wiley.com/doi/10.1002/adsr.202200010
DOI: 10.1002/adsr.202200010

Content Summary

- This is work done by researchers at Universities of the West of England and nchester with Wuhan textile university in China
- The team prepared reduced graphene oxide using the Hummer's method
- They used this to coat cotton yarn using a laboratory yarn dyeing machine
- The rGO coated cotton was electrically conductive and was used to embroider a piezoresistive sensor pattern onto clothing
- The embroidered sensor was sensitive enough to detect movement from breathing



- The graphene coated fibre was comparable with metallic yarns
- The graphene fibre was more biocompatible and sustainable than metallic yarns
- The team also investigated the washability of the graphene sensor and concluded it needed a coating of polyurethane or hot melt encapsulating to be wash-poof

Significance:

- A straightforward and scaleable method for making cotton yarn electrically conductive for embroidered sensors
- This can create e-textiles with pressure sensors for medical applications
- One issue is the washability of the rGO coating
- The coated yarn would need further coating with a water-resistant polymer.

Batteries

Graphene Manufacturing Group announces Graphene-aluminium-ion battery performance improvements

https://www.proactiveinvestors.com/companies/news/995011/graphene-manufacturing-group-announces-battery-cell-and-graphene-production-improvements-in-latest-update-995011.html

https://insideevs.com/news/598656/tesla-4680-battery-cell-specs/

Content Summary

- Graphene Manufacturing Group (GMG) said it has been steadily improving the performance of its graphene-aluminium-ion battery
- The calculated energy density has increased by 93% to 290-310 watt-hours per kilogram (Wh/kg)
- The power density has increased by 33% to around 9,350 watts per kilogram (W/kg) since the last update on June 22, 2021
- The previous figures are detailed in vol 5 iss 6 p.30

Graphene-Aluminium ion coin cell batteries. Image credit GMG.

- This is impressive performance. Energy density is the key number to watch for battery development
- The GMG value of approximately 300Wh/kg is comparable with the latest Tesla Battery with an energy density in the range of 272 to 296 Wh/kg (see source reference link above)

Significance:

- GMG are the only company making advanced in energy density of their batteries
- Their graphene-Al-ion battery rivals the energy density of the best Lithium ion
- It is tempting to make the connection with electric vehicle batteries – however remember that the GMG batteries are small coin cells and pouch cells which may not transfer directly for EV use.
- This is still an impressive achievement.

MARKET
Energy Management
APPLICATION
Batteries
PRODUCT TYPE
Graphene Nanoplate
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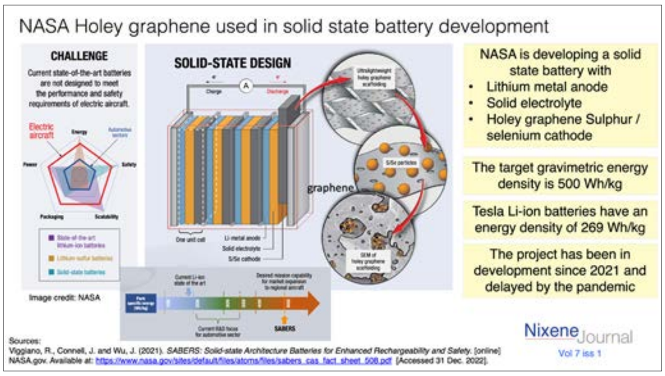
MARKET
Aerospace
Automotive
Energy Management
APPLICATION
Batteries
PRODUCT TYPE
Graphene Nanoplate
Back to Contents

NASA's new solid state graphene battery could overtake lithium ion

Viggiano, R., Connell, J. and Wu, J. (2021). SABERS: Solid-state Architecture Batteries for Enhanced Rechargeability and Safety. [online] NASA.gov. Available at: https://www.nasa.gov/sites/default/files/atoms/files/sabers_cas_fact_sheet_508.pdf [Accessed 31 Dec. 2022].
https://www.fastcompany.com/90801710/nasa-graphene-battery-electric-flight

Content Summary

- This is an article by the Fast company
- NASA has been working on a solid-state graphene lithium metal battery
- This is part of a high-risk high reward research programme called SABERS
- The acronym stands for Solid-state Architecture Batteries for Enhanced Rechargeability and Safety.



- The work is being done at NASA's Glenn Research Center in Cleveland, Ohio, and NASA's Langley Research Center in Hampton, Virginia
- The battery is based on cells made from the following components
  - The anode is lithium metal (a solid, unlike lithium ion, which is more like a gel).
  - The cathode is a combination of sulphur and selenium, whose particles are arranged in a holey graphene structure invented and patented by NASA.
  - Between the electrodes is the electrolyte, a solid material free of the flammable components of today's lithium-ion batteries.
- For more information on holey graphene https://www.youtube.com/watch?v=F9__-Gga1vk
- NASA's tests have shown astonishing performance
  - Energy density of 500 Wh/kg (compared with Li-ion at 260 Wh/kg)
  - Operating temperature maximum power consumption = 150°C
  - Not flammable or explosive even when severely damaged by impacts
- The NASA project lead says that EVs with these solid state batteries could be on the road in a 2025-28 timeframe

Significance:

- NASA have made a battery with double the energy density of Li-ion technology
- The battery fails safe on impact, has a maximum operating temperature of 150°C
- The project lead predicts the solid-state batteries could be available within 3 years

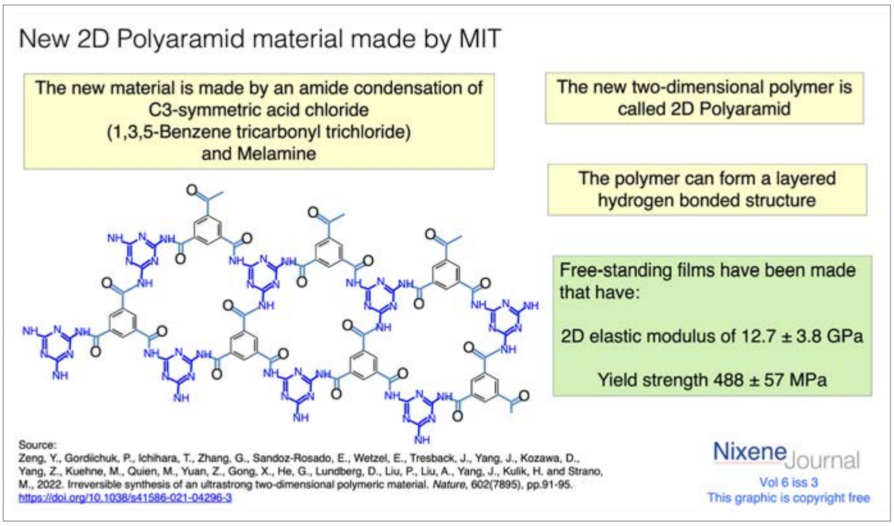
Coatings

New 2D material made by MIT

https://www.nature.com/articles/s41586-021-04296-3.pdf
DOI: 10.1038/s41586-021-04296-3

Content Summary

- This is work done by a team at the Massachusetts Institute of Technology (MIT) in the USA
- They made a new material by an amide condensation of 1,3,5-Benzene tricarbonyl trichloride and Melamine
- This created a flat polymer that they called 2D Polyaramid
- MIT seem to have made the first two-dimensional polymer made by wet chemistry



- The 2D polymer was made into free standing films and mechanically tested:
  - 2D elastic modulus of 12.7 ± 3.8 GPa
  - Yield strength 488 ± 57 MPa
- This compares with Kevlar
  - Yield strength 1240 MPa
  - http://www.tsgc.utexas.edu/tadp/1996/reports/tech/material2.html
- The 2 sheets do form a bulk material with hydrogen bonds between layers.

Significance:

- MIT call this material a 2D polyaramid
- The tensile strength of this material is modest when compared to Kevlar (an aramid polymer fibre)
- This is probably due to the presence of multiple voids in the 2D polymer sheet
- The fact the material forms layers that hydrogen bond should make it a useful material for making self-sealing coatings.

MARKET

Aerospace

Defence

APPLICATION

Anti-wear

Coatings

PRODUCT TYPE

Graphene Oxide (GO)

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29th April 2022

Nova Graphene awarded defence contracts to develop graphene enhanced corrosion-resistant materials for helicopter rotors

https://www.digitaljournal.com/pr/nova-graphene-awarded-two-defence-contracts-to-develop-corrosion-resistant-materials-for-helicopter-rotors

https://novagraphene.com

Content Summary

- Nova Graphene is a Canadian based graphene applications company
- They announced they have been awarded two contracts by Canada's Department of National Defence's Innovation for Defence Excellence and Security (IDEaS) program
- The project is to develop graphene-enhanced materials to protect helicopter rotors from erosion & wear due to exposure to sand, ice, and water.

Helicopter blades. Image credit: zujen, Pixabay

- Helicopter rotor blades do have leading edge erosion strips
- However, military use in more demanding environments needs very robust coatings
- A better coating means improved mission availability
- The first contract is to develop graphene-enhanced coatings for the entire rotor blade
- The second contract is to develop an improved leading-edge strip

Significance:

- Developing graphene enhanced anti-wear coatings for helicopter blades should reduce downtime when operating helicopters in abrasive environments
- If successful, this work should improve mission availability.

Appendix 1

The Navigator Headings

The content for the navigator headings is updated on a regular basis in response to reader feedback and the emerging content in the market.

MARKET	
Aerospace	Marine
Agriculture	Measurement Standards
Automotive	Mining
Biomedical	Mobile / Wearable Devices
Carbon Capture	Nuclear Industry
Caution	Oil & Gas
Civil Engineering Infrastructure	Packaging
Communications	Paper & Board
Construction	Personal Care
Defence	Pharmaceuticals
Electronics	Recycling
Energy Management	Regulations
Environmental	Research & Development
Fast Moving Consumer Goods (FMCG)	Security
Flooring	Separation Membrane
Graphene Standards	Sports
Grid Energy Storage	Sustainability
Heating Ventilation Air Condensing (HVAC)	Textiles
Legal	Transport
Luxury Goods	Water Treatment
Manufacturing	

Appendix 1 - continued

APPLICATION

2D Magnets	Composites – Silicon	Heating
3D Printing	Composites – Starch	Heat Management
Adhesive	Computing	Hydrogen Economy
Air Purification	Conductive Inks	Hydroponics
Anti-bacterial	Conductive Membrane	Infection Control
Anti-biofilm	Cooking	Internet of Things (IOT)
Anti-cancer	Cooling	Irrigation
Anti-corrosion	Cosmetics	Lighting
Anti-counterfeiting	Cosmetic Dentistry	Lightning Protection
Anti-fouling	Cryogenic Containment	Lightweighting
Anti-mosquito	Cutting Tools	Lubricants
Anti-static	De-icing	Membrane – Gas Separation
Anti-virus	Desalination	Membrane – Ion Separation
Anti-wear	Desiccant	Membrane – Liquid Separation
Armour	Displays	Memory
Art Conservation	Down hole drilling process aid	Metals recovery from waste
Barrier – Vapour / Gas	Drilling Mud	Microscopy
Batteries	Electromagnetic Interference Shielding (EMI)	Mirrors
Behaviour Modification	Face Mask	Misinformation
Catalysis	Flame Tetardant	Moiré Engineering
Clothing	Flexible Displays	Nanocapillaries
CO2 Reduction	Fluorescence Quenching	Nanoelectronics
Coatings	Fuel Additive	Nanoelectromechanical Systems NEMS
Complementary metal-oxide-semiconductor (CMOS)	Fuel Cells	Neuromorphic Computing
Composites – Asphalt	Fuel Manufacture	Noise Reduction
Composites – Ceramic	Geothermal	Optoelectronics
Composites – Gypsum	Graphene Metrology	Orthopaedics
Composites – Metal	Health & Safety	
Composites – Polymer		

Osmotic Blistering
Packaging – Food
Paint
Particle Physics
Patents
Pellicle
Personal Protection
Pharmacology
Phononics
Photonics
Pollution Control
Potable Water
Power Generation
Power Transmission
Printing
Propellant
Quality Control
Quantum Computing
Rail
Recycling
Refractory Products
Regulations
RFID
Roads
Sensors
Sensors – graphene field effect transistors GFET
Sensors – Magnetic
Solar Cells
Sound Enhancement
Spintronics
Strain Measurement
Supercapacitors
Superconductivity
Temperature Measurement
Terahertz (THz)
Testing Standards
Tether
Tissue Engineering
Touchscreen
Transistors
Twistronics
Tyres / Tires
Valleytronics
Virus Detection
Water Management
Watch
Wound Management

Appendix 1 - continued

PRODUCT TYPE

- 2D Polyaramid
- 2D Cuprous Iodid e(hCuI)
- 2D Quantum Dots
- Artisan Graphene (Handmade from graphite)
- Biphenylene Network (BPN)
- Borocarbonitrides
- Borophene
- Borophane
- Carbon Nanotubes
- Chemically Synthesised Graphene
- Chromium Trichloride 2D CrCl3
- CVD Graphene
- CVD Hexagonal Boron Nitride (hBN)
- Cyclocarbon
- Cyclodextrin functionalised Graphene Oxide (CD-GO)
- Diamane
- Edge Oxidised Graphene (EOG)
- Epitaxial Graphene on SiC
- F-Diamane
- Flash Graphene
- Fluorographene
- Grain boundary diffusion graphene
- Graphane
- Graphenes
- Graphene Aerogel
- Graphene Fibre
- Graphene Foam
- Graphene Hydrogel
- Graphene infused polymer opal (GIPO)
- Graphene Laminate (GL)
- Graphene Monoxide
- Graphene Nanoplate
- Graphene Nanoribbon
- Graphene Oxide Aerogel
- Graphene Oxide Dough
- Graphene Oxide Fibre
- Graphene Oxide Nanoplate
- Graphene Powder
- Graphene Quantum Dot (GQD)
- Graphene Super Laminate (Gsl)
- Graphenic Glass
- Graphite
- Graphitic Film
- Graphyne
- Green Graphene
- Heterostructure
- Hexagonal Boron Nitride (hBN)
- Hexagonal Diamond (Lonsdaleite)
- Homostructure
- Indium Selenide
- Janus Graphene
- Laser Induced Graphene (LIG)
- Lateral Heterostructure
- Moiré Superlattice
- Molybdenum Disulphide (MoS2)
- MoS2 Quantum Dot
- MXene
- Nano Graphene
- Other 2D Materials
- Perovskite
- Phosphate Graphene Nanoplate
- Phosphorene (Black Phosphorous)
- Plumbene
- Pyrolytic Carbon
- Reduced Graphene Oxide Nanoplate
- Single Crystal Graphene
- Single Crystal Graphite
- Single Crystal hBN
- Tungsten Diselenide (WSe2)
- Tungsten Disulphide (WS2)
- Turbostratic Graphene
- Transition Metal Carbo-chalcogenides (TMCC)
- Transition Metal Di-chalcogenides (TMD)
- U-carbon
- Van der Waals Heterostructure
- Van der Waals Homostructure

About

The Nixene Journal is a monthly review of the technology and markets relating to graphene and other 2D materials. Because it takes no advertising or sponsorship it can provide an independent view. The style is to create clarity from the complexity inherent in the science and research and present it in a readable and digestible format.

The Journal's origin is through the research and analysis of Adrian Nixon our Editor in Chief. Adrian is an experienced, qualified scientist (Chartered Chemist and Member of the Royal Society of Chemistry) and has published regular content in industry journals and website blogs since 1999. He is an advisory board member of StellarModal, a non-profit international association for the advancement of trade research and enterprise development of space commerce. Adrian is also a member of the board of directors of the International Space Elevator Consortium (ISEC).

The Journal began in 2017 as a private research project that was needed to create information and understanding about the emerging world of graphene and other 2D materials. This quickly became a significant regular undertaking as the amount of development activity grew. At the time of writing there are some 129,000 academic papers published each year and as much again reported business and market activity.[1]

We now summarise this vast array of content through the Nixene Journal which is distributed to some of the world's leading organisations who wish to be kept informed of the progress graphene is making in becoming a practical reality for use in and around the world. We cover a wide range of topics from energy management, composites, separation membranes, nano medicine, coatings and other emerging markets and applications.

The Journal has two basic sections, one focussing on identifying and explaining the emerging technology and the other analysing the business and markets activity. In effect, we take the content and determine the 'so what?' irrespective of industry segment or location. We are always looking for ways in which we can improve this publication so please do contact us if there is something important you think could be added.

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[1] Nixon, A., Whieldon, R. and Nelson, D., 2021. Graphene: Manufacturing, Applications and Economic Impact. 1st ed. Manchester: Nixene Publishing, pp.21-26.

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Each issue explains the technology and commercial activity taking place.

Since 2017, each month we report developments in the world of graphene and 2D materials with the Nixene Journal™.

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