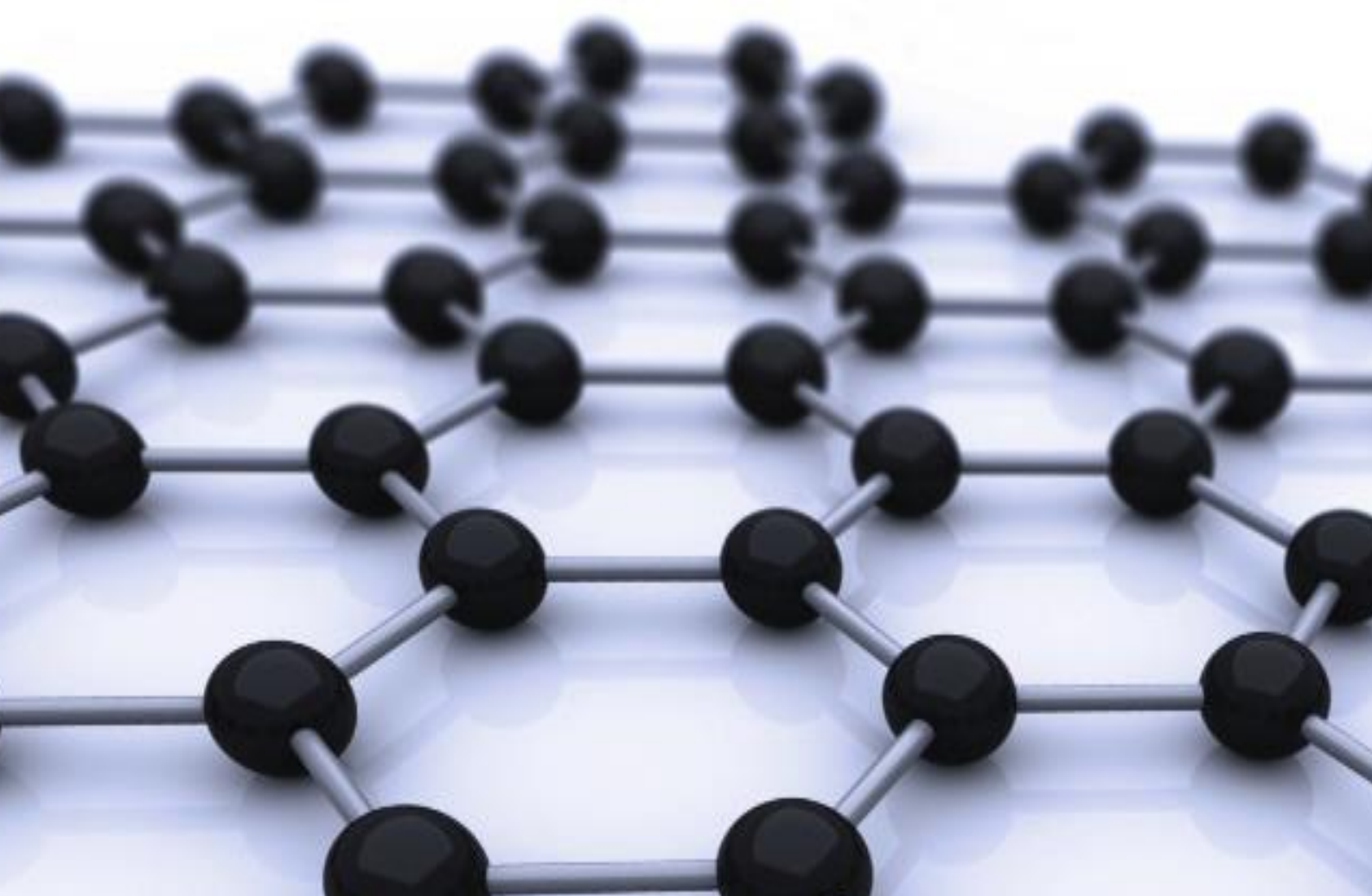
Nixene Journal

Trends in Graphene Applications

May 2020



Disclaimer

Nixene Publishing Limited, the author and publisher, have made every effort to ensure that the information in this publication was correct at the time of going to press. Nixene Publishing Limited, the author and publisher, do not assume and hereby disclaim any liability to any party for any loss, damage or disruption caused by errors or omissions, whether such errors or omissions result from negligence, accident or any other cause.

Introduction

This short paper provides an analysis of graphene the related applications that have been between reported on in the Nixene Journal between October 2017 and April 2020. It illustrates the top 20 applications and trends over time for these applications.

Background

The Nixene Journal is published monthly summarising technology and market developments in the world of Graphene and 2D.

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 standard format for the Nixene Journal can be found in Appendix 1 whilst a summary of the current navigator headings can be found in Appendix 2.

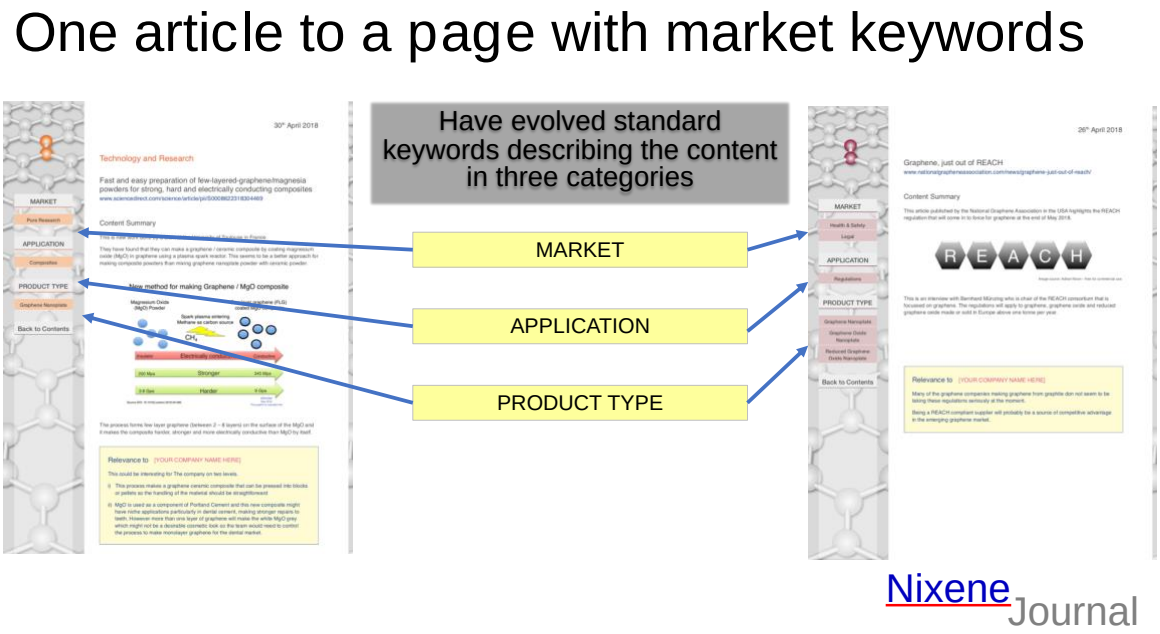


Figure 1: Navigator Headings

Word Cloud Analysis

We reviewed all the articles published since we started the Journal in October 2017 and April 2020 (the most recent Journal) against the standardised nomenclature that we use. The purpose was to identify the emerging trends in graphene applications over the past 2½ years, to see what is being worked on and reported.

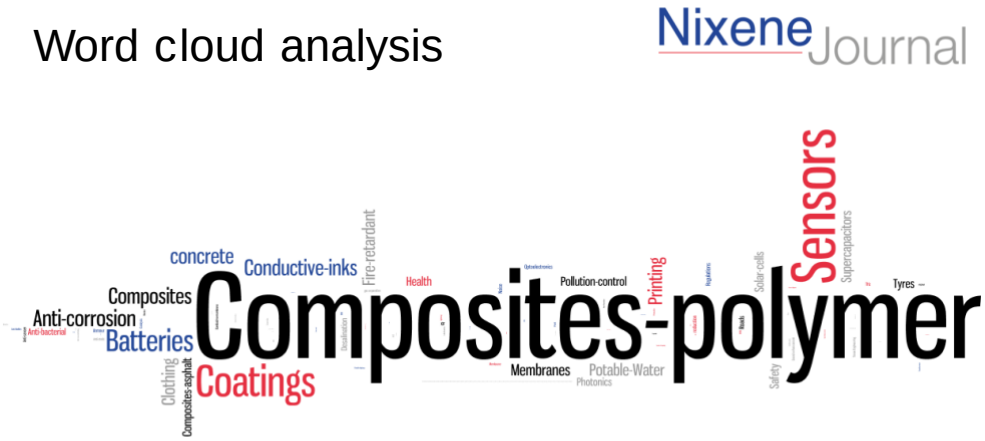


Figure 2: Word Cloud showing the dominance of Polymer Composites

First of all, we created a Wordcloud to create a visual representation to identify the frequency or importance of each application referenced in the Journal. Figure 2 illustrates our initial search.

It is quite clear from this that Polymer Composites are by far and away the greatest area of activity that is being worked and reported on.

In fact, Polymer Composites are so dominant in the Word Cloud that other areas of activity have been obscured. We therefore removed them and reset the Word Cloud. Figure 3 illustrates these other areas of application.

Figure 3: Word Cloud illustrating other Graphene applications

Top 20 Applications

Next we ranked the number of applications referenced in the Nixene Journal in order to our identify top 20, see Figure 4.

Rank	Application	No. of references
1	Composites - polymer	173
2	Sensors	88
3	Coatings	63
4	Batteries	44
5	Heat Management/Transfer	37
6	Anti-corrosion	33
7	Composites – concrete & cement	32
8	Conductive Inks	32
9	Clothing	26
10	Fire Retardant	25

Rank	Application	No. of references
11	Potable Water	24
12	Membranes	23
13	Supercapacitors	20
14	Composites - asphalt	18
15	Health & safety	18
16	Pollution control	18
17	Solar cells	18
18	Tyres	18
19	Photonics	16
20	Printing	15

Figure 4: Top 20 Graphene applications referenced in the Nixene Journal

Trends over time

We then looked at the trends in graphene applications over time. This is mainly a look back over time to see which applications started 'moving' and perhaps to give us an indication of the direction of travel for future trends.

Figure 5 illustrates these trends, with 3 clear front runners - Polymer composites, Sensors and Coatings.

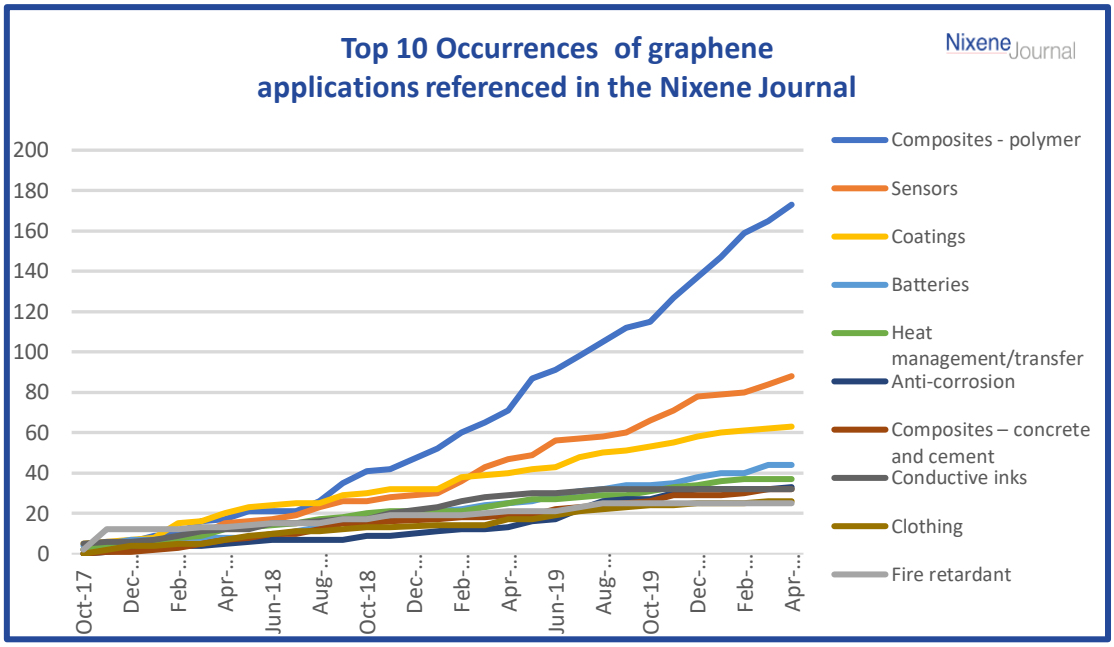


Figure 5: Trends over time in the top 10 graphene applications referenced

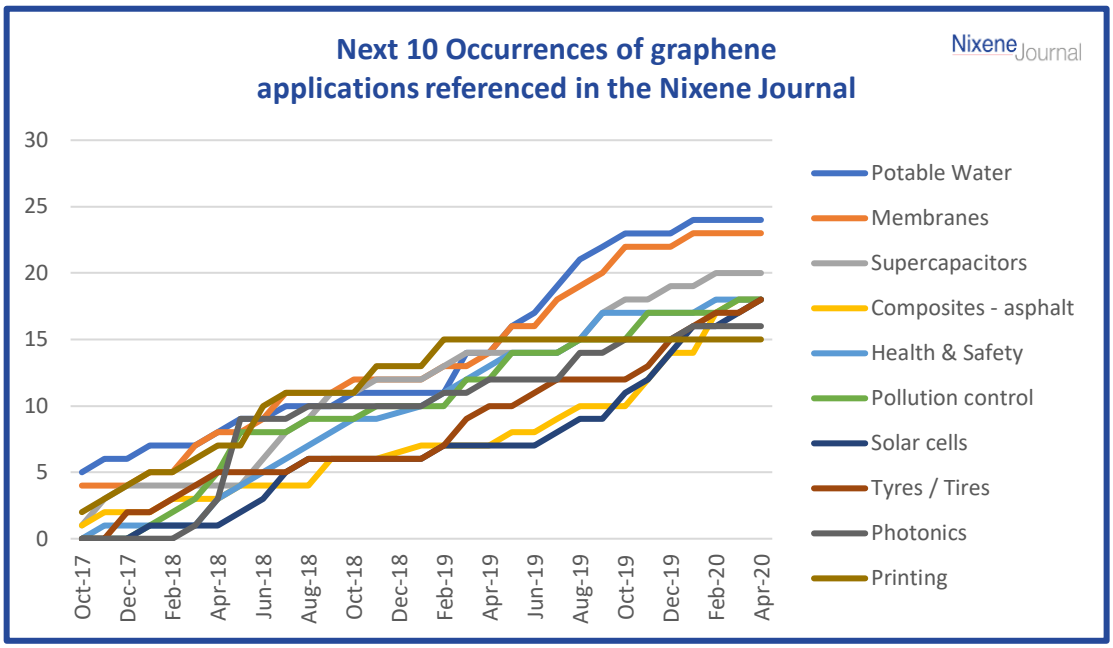
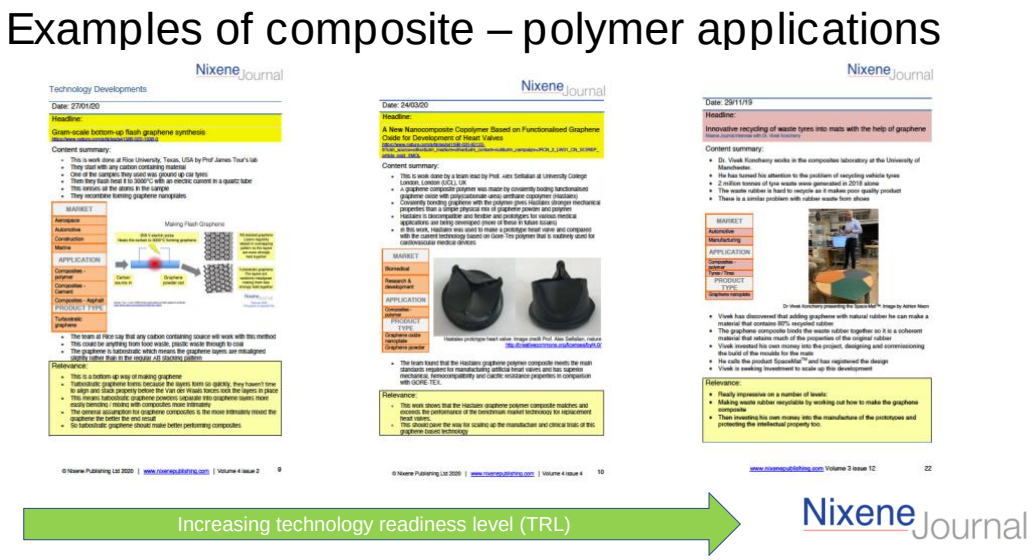


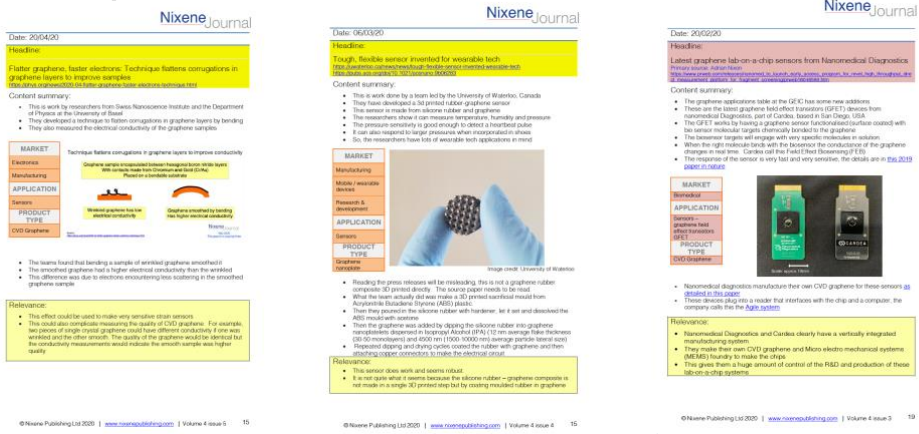
Figure 6 illustrates the trends for the next 20 graphene applications referenced in the Journal. It should be noted that the numbers here are relatively small with no application being referenced more than 25 times.

Examples of Applications in the Nixene Journal

By way of illustrating the 'navigator heading' and how we use this nomenclature in the Nixene Journal, below are examples of articles from recent Journals.

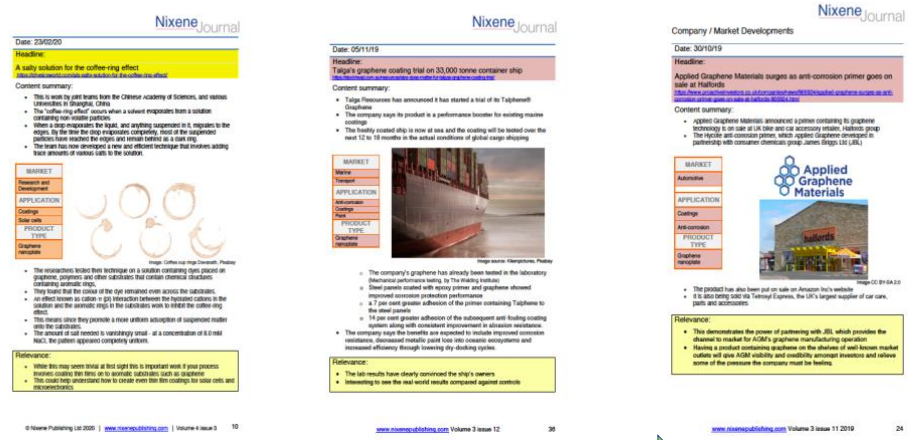


Examples of sensor applications



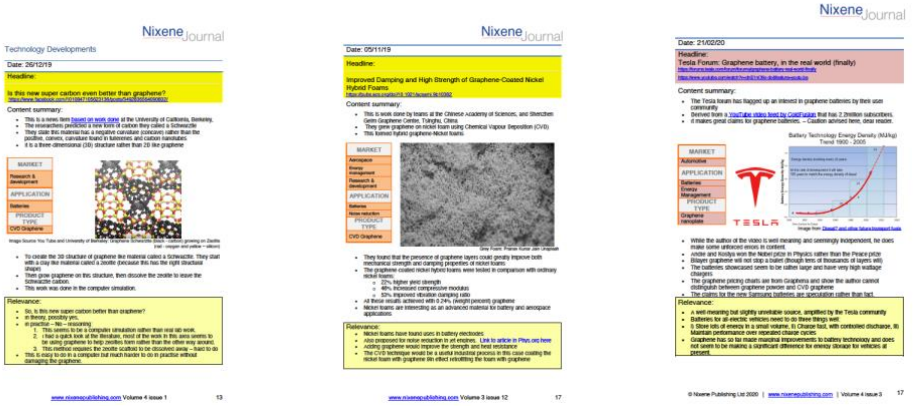
Increasing technology readiness level (TRL)

Examples of coating applications



Increasing technology readiness level (TRL)

Examples of battery applications



Increasing technology readiness level (TRL)

Appendix 1: The standard format for the Nixene Journal

Each monthly Journal reports in date order for the month, with the most recent work first.

Date: dd/mm/yy

Headline:

Technology and Research are in Yellow

The source material is hyperlinked

Content summary:

A description of the source material translating technical jargon in to plain English as far as possible

Relevance:

Highlighting work that may be of interest and why

Date: dd/mm/yy

Headline:

Company / Market information in pink

The source material is hyperlinked

Content summary:

Relevance:

Highlighting work that may be of interest and why

Appendix 2: The navigator headings

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

Market
Aerospace
Agriculture
Automotive
Biomedical
Caution
Communications
Civil engineering infrastructure
Construction
Defence
Electronics
Energy management
Graphene Standards
Fast moving consumer goods (FMCG)
Legal
Luxury Goods
Manufacturing
Marine
Measurement Standards
Mining
Mobile / wearable devices
Oil & Gas
Packaging
Paper & Board
Research & development
Regulations
Security
Separation Membranes
Sports
Textiles
Transport
Water Treatment

Product Type	
Artisan graphene (handmade from graphite)	Graphene quantum dot (GQD)
Borocarbonitrides	Graphenic glass
Borophene	Graphite
Carbon nanotubes	Graphitic film
Chemically synthesised graphene	Graphyne
CVD Graphene	Heterostructure
CVD hBN	Hexagonal Boron Nitride (hBN)
Cyclocarbon	Homostructure
Cyclodextrin functionalised Graphene Oxide (CD-GO)	Indium Selenide
Edge oxidised graphene (EOG)	Laser Induced Graphene (LIG)
Epitaxial graphene on SiC	Lateral heterostructure
F-Diamane	Janus graphene
Fluorographene	Molybdenum disulphide (MoS_2)
Grain boundary diffusion graphene	MoS_2 Quantum Dot
Graphenes	MXene
Graphene aerogel	Other 2D materials
Graphene fibre	Nano graphene
Graphene foam	Phosphate graphene nanoplate
Graphene ink	Phosphorene (Black Phosphorous)
Graphene Monoxide	Plumbene
Graphene nanoplate	Reduced graphene oxide nanoplate
Graphene nanoribbon	Single crystal graphene
Graphene oxide aerogel	Tungsten diselenide (WSe_2)
Graphene oxide dough	Tungsten disulphide (WS_2)
Graphene oxide fibre	Transition metal Di-chalcogenides (TMDCs)
Graphene oxide nanoplate	
Graphene powder	

Application		
3D Printing	Geothermal	Solar cells
Adhesive	Graphene metrology	Sound enhancement
Anti-bacterial	Health & Safety	Spintronics
Anti-biofilm	Heat management	Strain measurement
Anti-cancer	Internet of Things (IOT)	Supercapacitors
Anti-corrosion	3D Printing	Superconductivity
Anti-counterfeiting	Irrigation	Temperature measurement
Anti-mosquito	Lubricants	Terahertz (THz)
Anti-static	Lighting	Tether
Anti-virus	Lightning protection	Tissue Engineering
Armour	Lightweighting	Touchscreen
Barrier – vapour / gas	Membrane – gas separation	Twistronics
Batteries	Nanoelectromechanical systems NEMS	Tyres / Tires
Catalysis	Noise reduction	Virus detection
Clothing	Optoelectronics	Water management
Coatings	Paint	Watch
Composites - polymer	Patents	Wound management
Composites - asphalt	Personal protection	
Composites – concrete and cement	Photonics	
Composites - silicon	Pollution control	
Conductive inks	Potable Water	
Conductive membrane	Power generation	
Cooling	Power transmission	
Cosmetics	Pressure measurement	
Cosmetic dentistry		
Cryogenic containment	Printing	
De-icing	Propellant	
Desalination	Quantum Computing	
Desiccant	Rail	
Down hole drilling process aid	Refractory products	
Electromagnetic interference shielding (EMI)	Regulations	
Face mask	RFID	
Fire retardant	Roads	
Flexible displays	Sensors	
Fluorescence quenching	Sensors – graphene field effect transistors GFET	
Fuel cells	Sensors - magnetic	

About

The Nixene Journal is brought about through the research and analysis of Adrian Nixon, 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. Adrian is an advisory board member of the National Graphene Association in the USA.

The Journal began 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 twenty-five thousand academic papers published each year and as much again reported business and market activity.

We now summarise this vast array of content through the Nixene Journal, published monthly and 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 journal so please do contact us if there is something important you think could be added.

Adrian Nixon
Editor

Rob Whieldon
Operations

Nigel Cliffe
Marketing

Neil Moon
Commercial

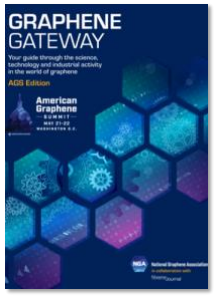
Debbie Nelson
Contributing Editor
& Project Manager

Joanna Whitehead
Graphic Design &
Print Management

The Nixene Journal operates on a subscription model and does not take advertising, allowing it to provide and independent view.

The Nixene Journal is dedicated to graphene and 2D materials

We operate a subscription model and do not take advertising
This means we have a completely independent view of this rapidly emerging field
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™
We also create special editions

Nixene Journal

If you would like to take out a subscription please contact us at:

info@nixenepublishing.com

Or visit our website at:

http://www.nixenepublishing.com/

Nixene Journal

Nixene Publishing Ltd
5th & 6th Floors I 51 Lever Street I Manchester I M1 1FN I United Kingdom
Nixene Publishing (USA)
2953 Bienville Blvd I #158 Ocean Springs I MS 39564 I USA
www.nixenepublishing.com
info@nixenepublishing.com