http://www.versarien.com/

Development of graphene and nanoparticle-based anti-microbials

November 2021

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Versarien (AIM:VRS)

Outline

- Introduction to Versarien
- Anti-microbial coatings
- Biocide Legislation

Versarien

~100 staff
~30 dedicated graphene professionals globally

Versarien utilise proprietary graphene materials technology to create innovative engineering solutions that are capable of having game-changing impact in a broad variety of sectors

The wider Versarien PLC

Versarien is now operating in South Korea, Europe and the USA, connecting the UK hub to provide globally an extraordinarily diverse bank of skills and experience

Our history

2010
Incorporation of Versarien Limited

2012
Won "Overall Winner 2012" at the UKTI Start-Up Games

2013
Floated on the AIM submarket on the London Stock Exchange

2014
Acquired majority holding in 2-DTech Limited, a developer and supplier of early stage graphene products from the University of Manchester

2015

2016
Acquired AAC Cyroma Limited

2017
Acquired majority holding in Cambridge Graphene Limited from Cambridge University

2018
Acquired majority holding in Gnanomat S.L.

2019
Incorporation of US-based sales arm Versarien Graphene Inc. and China-based subsidiary Beijing Versarien Technology Limited

2020
£5m loan provided by Innovate UK for graphene scale up

Acquisition of assets and IP from Hanwha Techwin, Korea

TOTALCARBIDE 2-DTECH aac cyroma CAMBRIDGE GRAPHENE Gnanomat Versarien

USA, China, Korea

UK R&D

Three staffed offices at graphene centres of excellence at Universities of Manchester, Cambridge and Belfast, including full access to GEIC and CGC.

MANCHESTER 1824 The University of Manchester
GRAPHENE ENGINEERING INNOVATION CENTRE

UNIVERSITY OF CAMBRIDGE

Ulster University
NIBEC Nanotechnology & Integratec Bioengineering Centre

WMG THE UNIVERSITY OF WARWICK

Graphene materials

Nanene™
Versarien

Technical Specifications

Property	Measurement	Method
Layers ≤5, ≤10, >10	60%, 90%, 10%	Raman [1]
Apparent Thickness	<3.5 nm / 10 layers	AFM [2]
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. 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, estimated by Raman, and 98% purity, Nanene™ is an outstanding graphene powder and is available today for commercial supply.

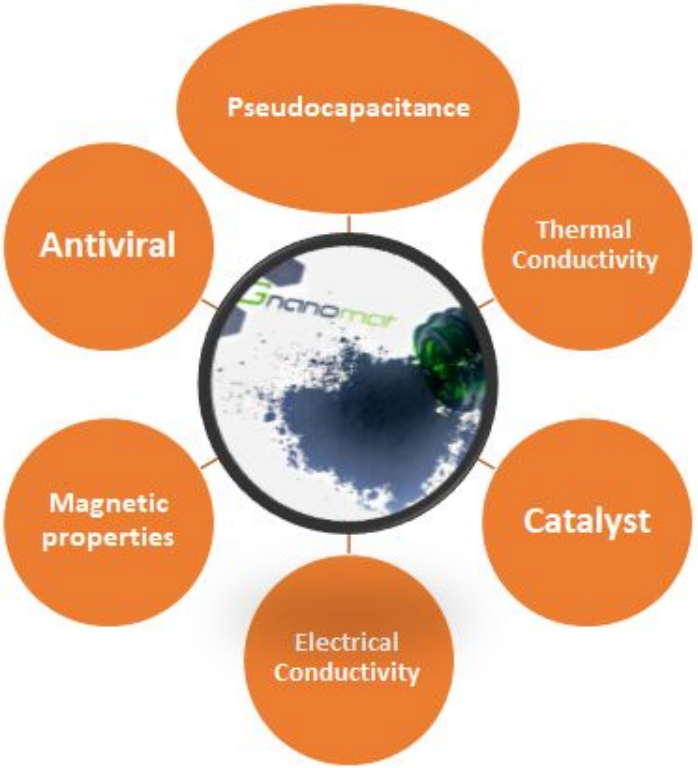
[1] Raman - bulk powder measurements - layer thickness estimated from 2D lineshape analysis based on A.C. Ferrari, Solid State Communications 143 (2007) 47–57.
[2] AFM - Nanene powder dispersed according to NPL's "Good Practice Guide: Characterisation of the structure of graphene, GPG 145" using N-methyl-2-pyrrolidone (NMP) solvent, with 30 minute sonication at each dilution step.

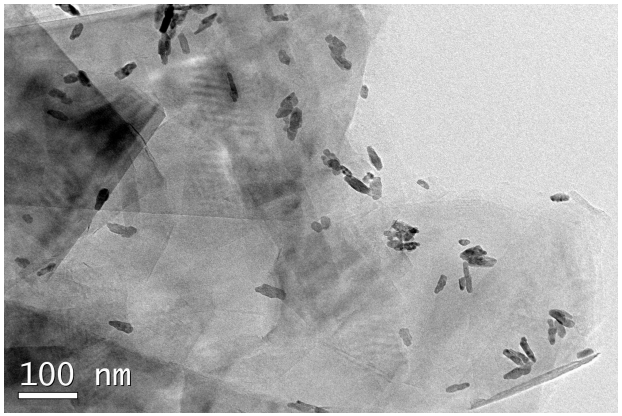
GRAPHINKS

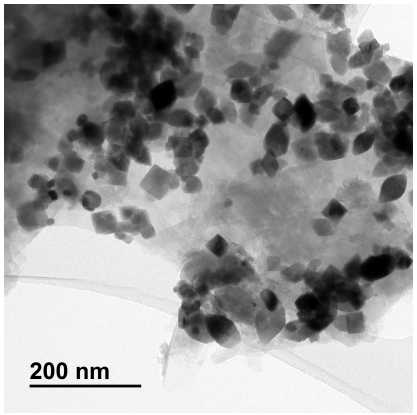
GRAPHINKS™ are printable graphene and related material (GRM) inks and coatings that bring multi-functionality (high electrical and thermal conductivity, fire retardation, UV protection, etc.), produced via a high pressure homogenisation process that offers high yield and uniform size distribution. We have 'standard' graphene inks for different deposition methods from inkjet to screen printing.

Hybrid nanomaterials manufacturing

- IP protected process to manufacture hybrid materials of graphene and metal (oxide) nanoparticles
- Improve and add new properties to graphene
- Environmentally friendly raw materials
- Manufacturing following industrial protocols
- Very **versatile** platform for the design and optimization of advanced materials



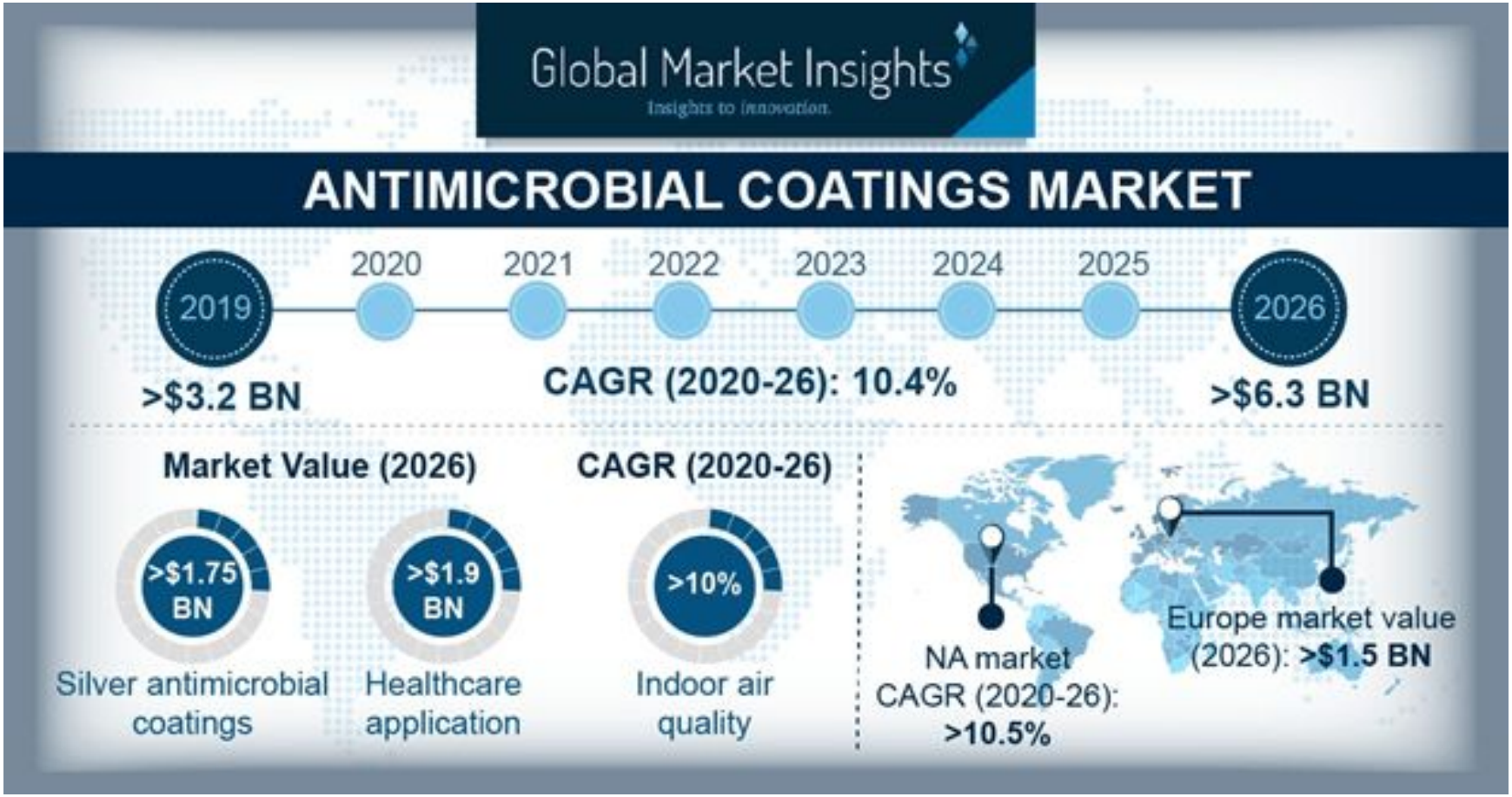




Certifications

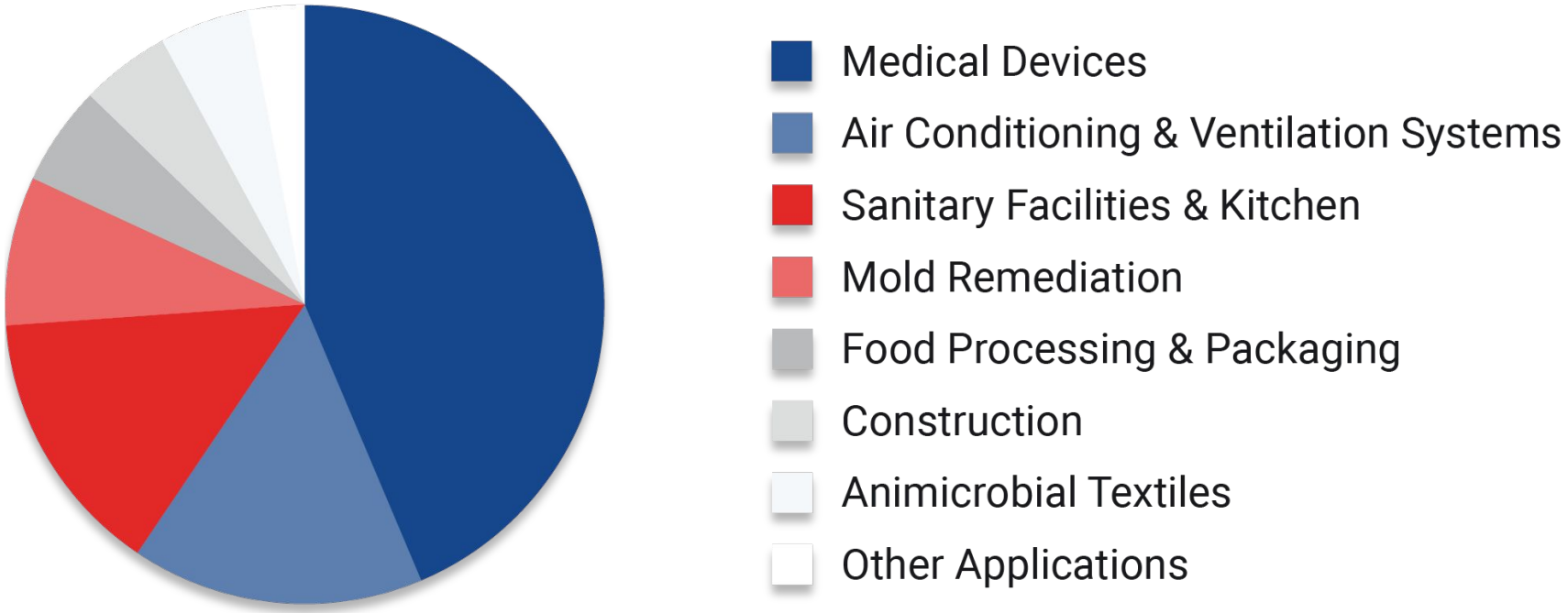
- Versarien® are the world's only company to pass the Verified Graphene Producer program as administered by The Graphene Council and independent testing at National Physical Laboratory (NPL)
- EU and UK REACH (Registration, Evaluation, Authorization and Restriction of Chemicals) registered for manufacturing and exporting graphene at 1-10 tons per annum
- Quality Management Systems ISO9001:2015 certified

Anti-microbial coatings market



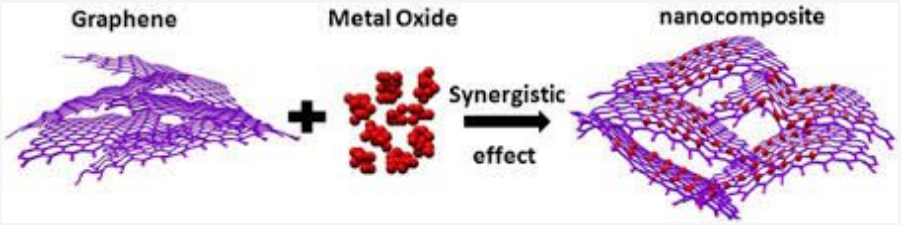
Anti-microbial coatings market

Global Antimicrobial Coatings Market Share, By Application, 2020 (%)



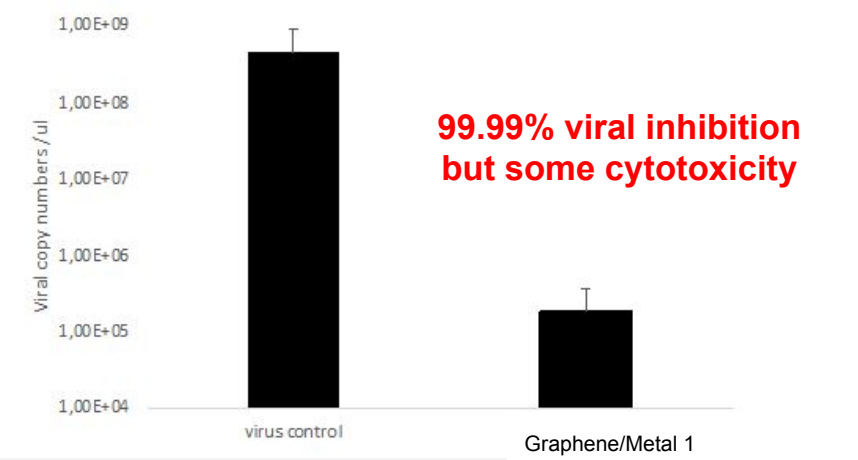
Source: www.grandviewresearch.com

SARS-CoV-2 Testing

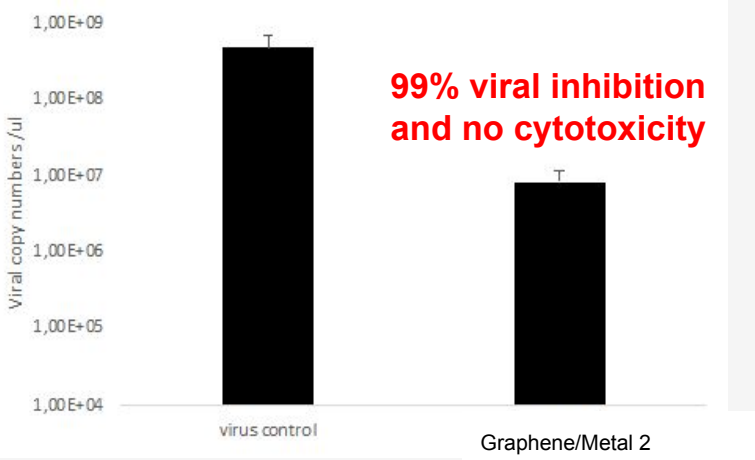


- Powder materials suspended in PBS (15%)
- SARS-CoV-2 premixed with materials
- Filtrate of the mixture is used to transfect VeroE6 cells.
- qRT-PCR performed to detect viral copies after infection experiment.
- All experiments performed at a BSL3 lab in Turkey.

Graphene/Metal 1



Graphene/Metal 2

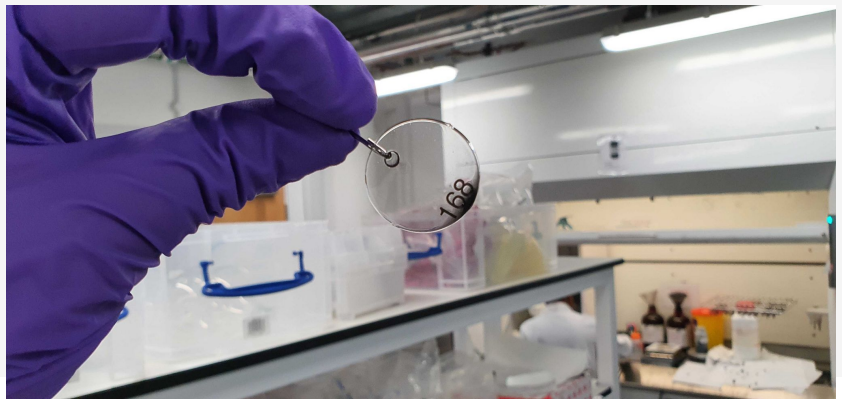


The testing was carried out in-line with a protocol defined by Pezzoti *et al.*, bioRxiv, 20 June 2020, in "Rapid Inactivation of SARS-CoV-2 by Silicon Nitride, Copper, and Aluminum Nitride", a copy of which can be found at: https://doi.org/10.1101/2020.06.19.159970

Antimicrobial thermoplastic coatings

Airway Medical Suction Unit (AMSU™)

Optically transparent anti-microbial coatings in development

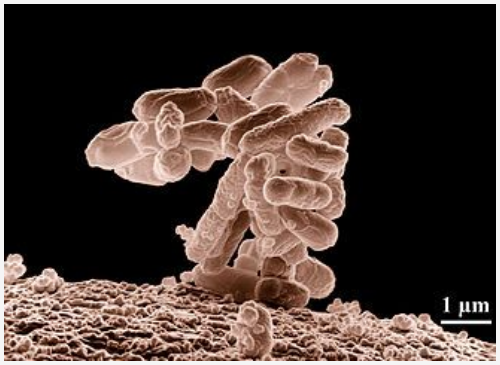


BS EN ISO22196 testing

Staphylococcus aureus

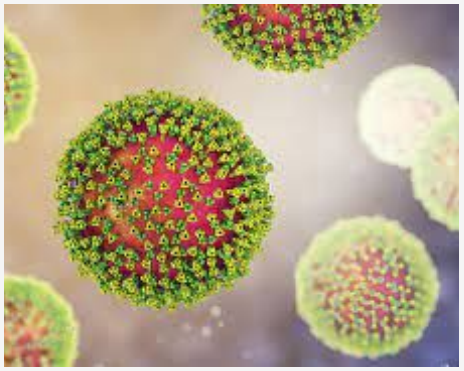
S. aureus is the most dangerous of all of the many common staphylococcal bacteria. These gram-positive, sphere-shaped (coccal) bacteria often cause skin infections but can cause pneumonia, heart valve infections, and bone infections.

Escherichia coli



E. coli, is a Gram-negative, facultative anaerobic, rod-shaped, coliform bacterium of the genus Escherichia that is commonly found in the lower intestine of warm-blooded organisms.

Bacteriophage MS2



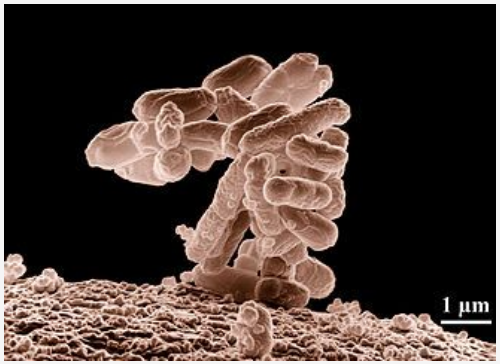
MS2, is an icosahedral, positive-sense single-stranded RNA virus that infects the bacterium E. coli and other members of the Enterobacteriaceae.

MS2 bacteriophage has been proposed as a conservative surrogate for the SARS-CoV-2 virus, as non-enveloped viruses are more resistant to decontamination than enveloped, lipid viruses.

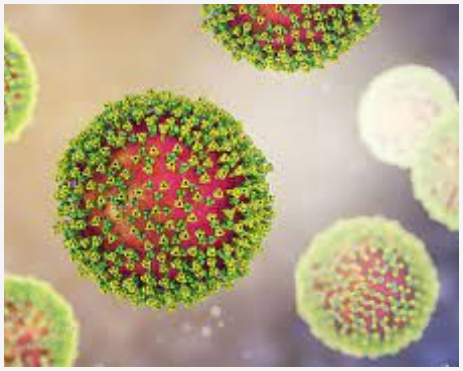
BS EN ISO22196 testing

Staphylococcus aureus

Escherichia coli



Bacteriophage MS2

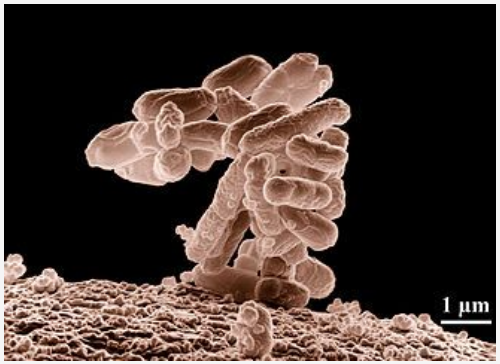


T = 24 h	**S. aureus** Reduction %	**E. coli** Reduction %	**MS2** Reduction %
Control	Slight increase	Slight increase	45.5 %
Graphene	94.5%	29x increase	98.15%
Graphene/Metal	>99.99%	>99.99%	99.11%
Graphene/Metal *(10 x less dose)*	>99.99%	>99.99%	95.67%

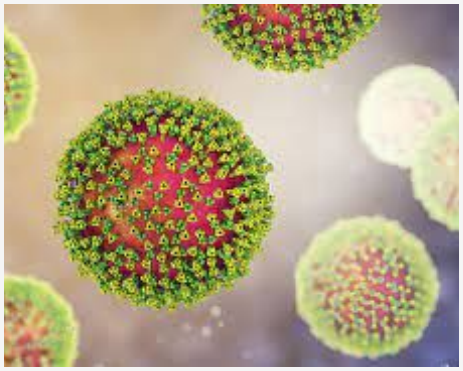
BS EN ISO22196 testing

Staphylococcus aureus

Escherichia coli

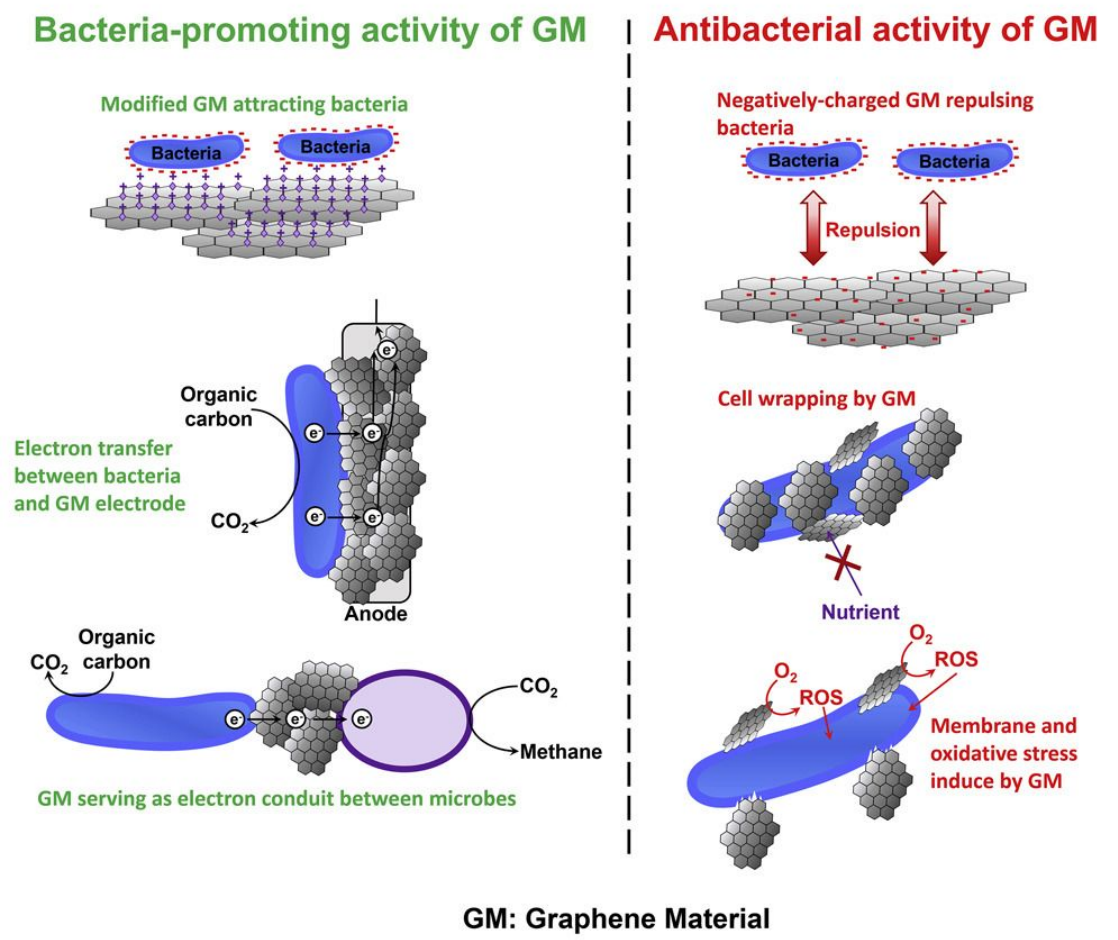


Bacteriophage MS2



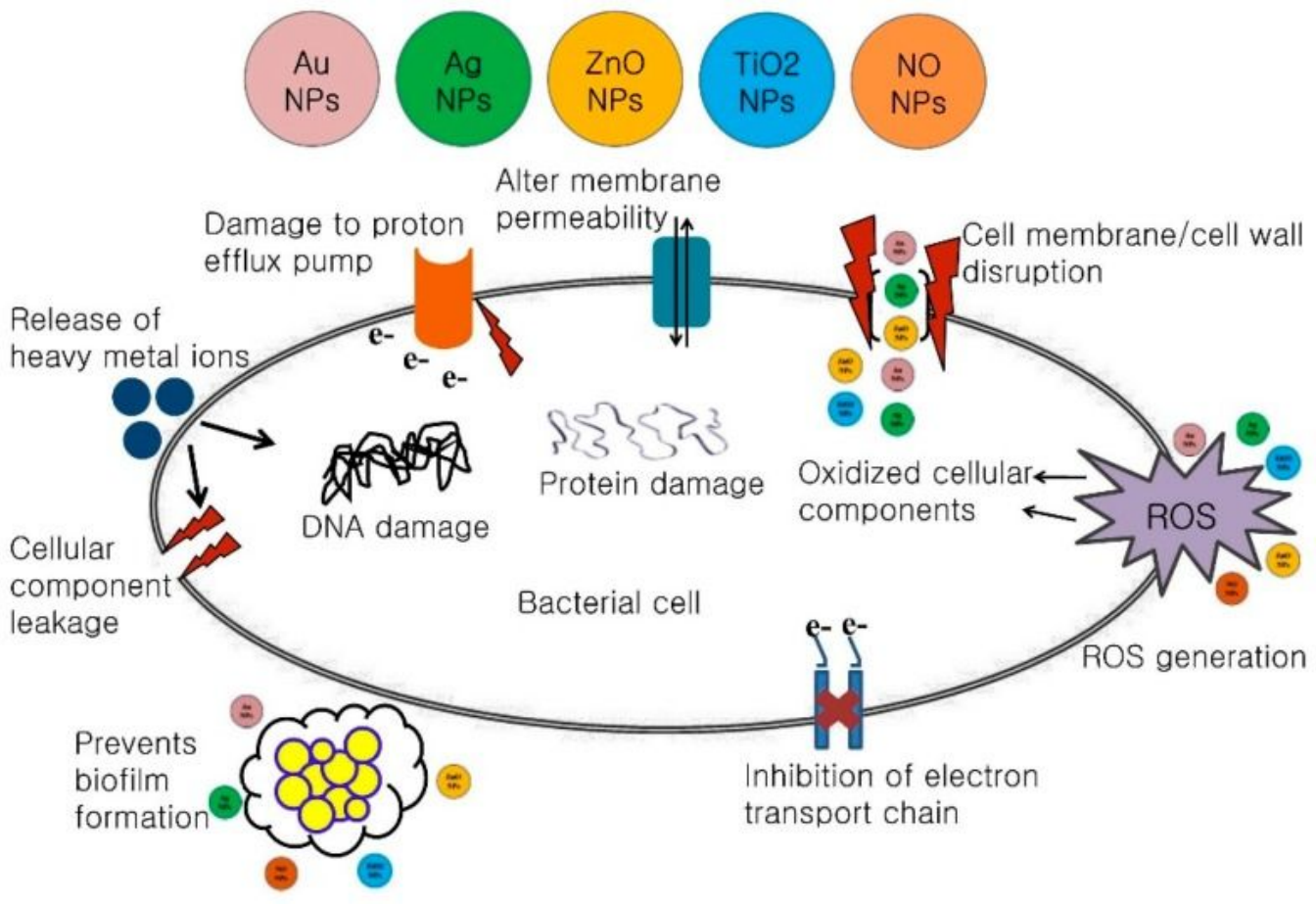
T = 1 h	**S. aureus** Reduction %	**E. coli** Reduction %	**MS2** Reduction %
Graphene/Metal *(10 x less dose)*	>99.86%	>99.24%	99.66%

Graphene interactions with bacteria



iScience, 23 (12), **2020**, 101787

Metal nanoparticle interactions with bacteria



Int J Mol Sci., 20 (10), ***2019***

Biocide legislation

- To utilise the key graphene related materials and hybrid nanomaterials in commercial products, it is important to consider “active substance” registrations as part of global biocide legislation

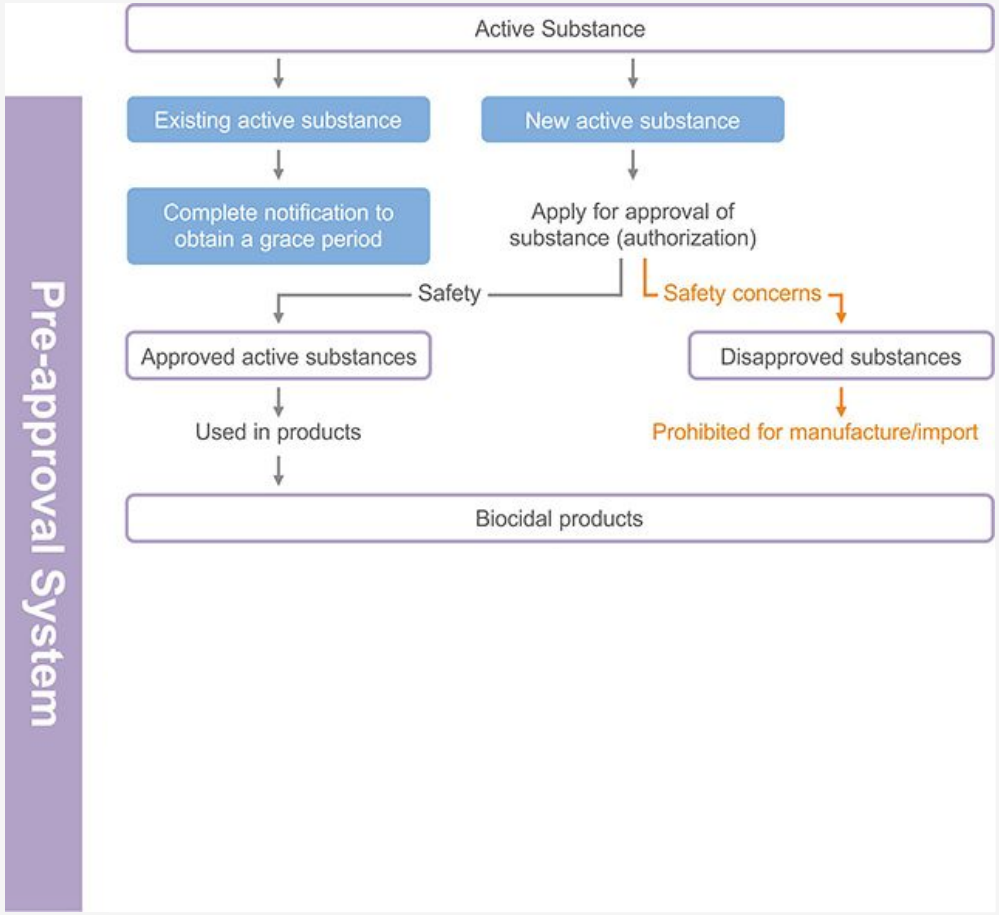
  - In the EU, biocides are regulated by the **Biocidal Products Regulation (BPR)** regulation (EU) No 528/2012 enforced by the European Chemicals Agency (ECHA)

  - In the US under the **Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)**, enforced by the Environmental Protection Agency (EPA)

- Biocide legislation is becoming more prevalent across the world. Major markets like Brazil, Russia, India and China have enacted or are in the process of passing their own biocide legislation.

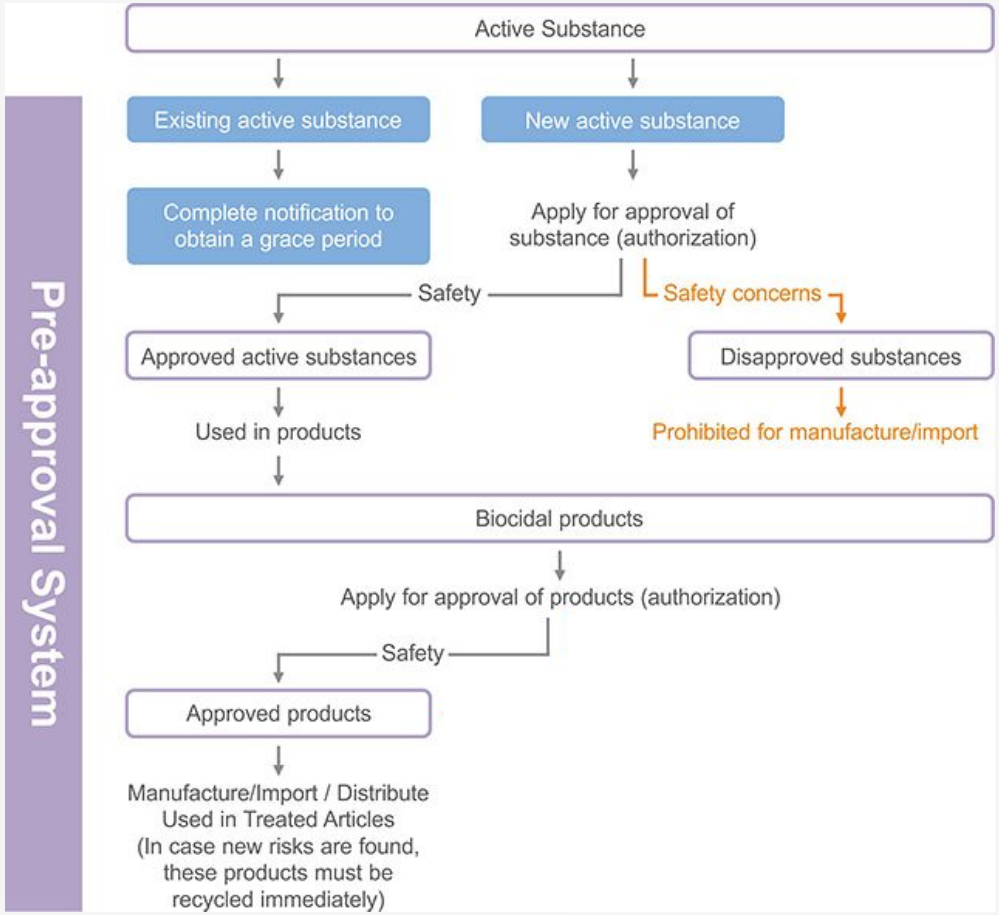
A Comparative Review of Biocidal Legislation in the EU, US and Canada
Jerry Miller, Senior Regulatory Consultant, Compliance & Risks, October 2020

Biocide legislation



https://www.cirs-reach.com/news-and-articles/K-BPR-Consumer-Chemical-Products-and-Biocides-Safety-Act.html

Biocide legislation



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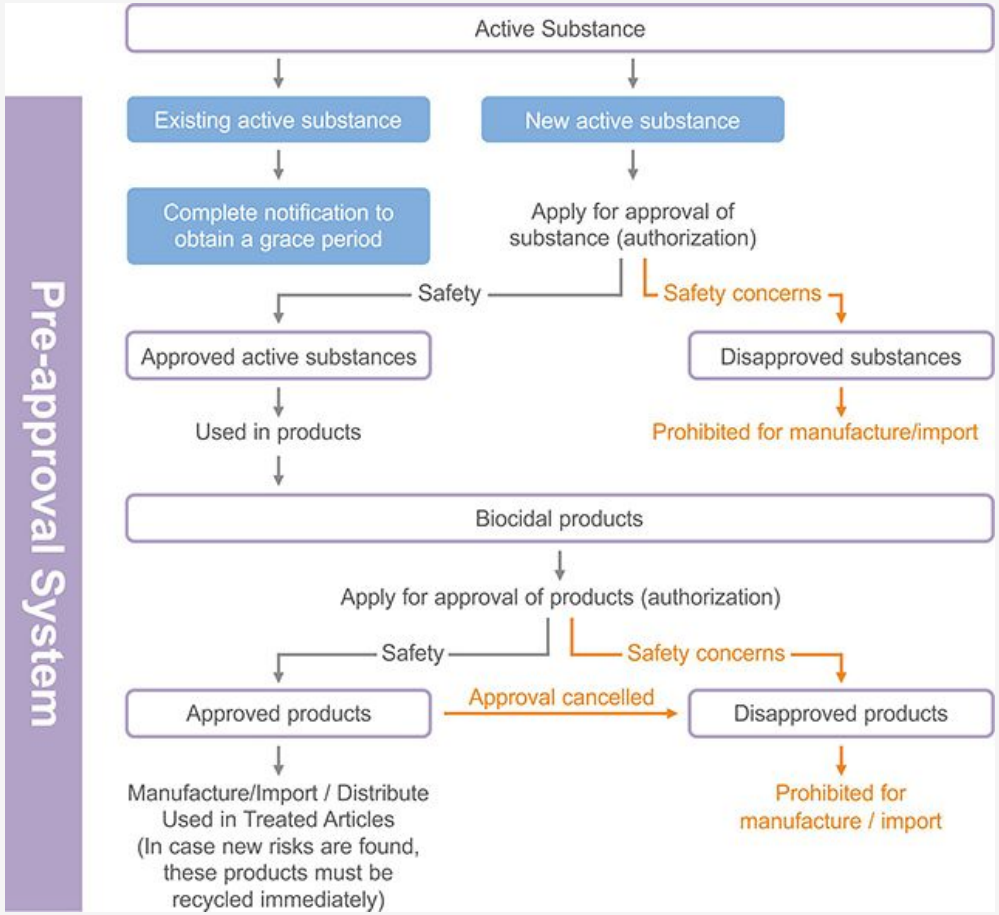
Biocide legislation



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2d materials in medical applications

clinicians without risking infection of either party. Using these systems, patients can self-report symptoms and behaviours, facilitating remote monitoring by clinicians, and the data can be used by national and global health agencies to implement coordinated control strategies.

Suit of armour

Conventional protective clothing can be heavy, bulky in nature causing a lack of mobility and poor breathability, and may be insufficient in protecting against pathogens and hazards. In some countries, the environment is extremely hot and humid, limiting healthcare workers' ability to work in personal protective equipment (PPE) for a long time. PPE modified with GRMs can be an effective means to overcome some of these limitations.

Graphene-based fabrics for smart textiles have already been developed to achieve enhancements in weight, breathability, heat dissipation, comfort, mechanical strength, anti-microbial activity, resistance to abrasion, durability and flexibility. In these cases, graphene can be incorporated into a textile as part of the polymer fibres, or applied as a coating to the garment during or after manufacture.

In the event of a pandemic, involving an airborne/droplet transmissible agent, wearing a face mask in public areas can impede the spread of an infectious disease by preventing both inhalation of infectious droplets and their subsequent exhalation and dissemination.

In face masks, the efficiency of the currently used polypropylene layers can be improved by incorporating graphene or hexagonal boron nitride (hBN)-based materials. The presence of GRMs increases surface energy and roughness of the individual polymeric fibres, enabling better air permeability and electrostatic binding of the virus, in addition to the physical barrier provided by the lamella structure. Also, photothermal, photocatalytic and conductive properties of graphene can be used for heat- or light-mediated inactivation of trapped viruses on used PPE, extending its lifetime.

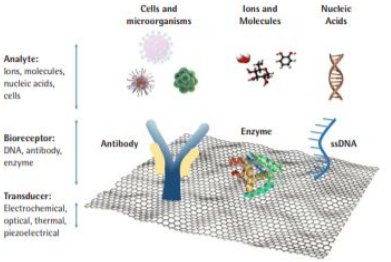
Meanwhile, GRMs can also be used to engineer self-sanitising materials and surfaces to mitigate fomite transmission. They are easily incorporated as coatings on high-touch surfaces such as doorknobs, light switches, smart phones, sinks, toilets, walls, as well as gowns, gloves, respirators and goggles.

Decontaminating surfaces to contain the virus is vital. However, chemical-based sanitisation involves intensive labour and materials, is impractical for covering all exposed areas and needs to be reapplied periodically.

The anti-microbial effect of graphene can be enhanced in combination with common anti-microbial materials, such as different metal/metal oxide nanoparticles – silver, iron, copper, zinc, etc. – and photocatalysts (TiO_2) to make composites that bring synergistic effects.

Such graphene composites can be introduced in a polymer matrix to make moulded articles such as mobile phone covers, hospital bed components or on surfaces as a coating. Even after a virus outbreak, these coatings can be used in places such as hospitals and care homes to offer a safe environment to those with a diminished immune system.

"Graphene related layered materials could be the basis of several technologies to diminish the impact of virus-related pandemics, but further development and realisation hinge upon sustained academic research and collaborative efforts with industrial partners."



Further development

GRMs could be the basis of several technologies to diminish the impact of virus-related pandemics, but further development and realisation hinge upon sustained academic research and collaborative efforts with industrial partners.

The UK has a large-scale manufacturing capacity and commercial availability of GRMs, a strong academic research leadership, and a knowledge base in materials science and biotechnology, with capacity for material and device characterisation, modelling and simulation, and standards bodies with global reputations (the British Standards Institution and the National Physical Laboratory, for example).

Cooperation among diverse researchers with complementary expertise, further industry-academia collaborations, including relevant topics for future funding calls, and initiating discussions with funders and stakeholders for making the best use of the materials are imminent approaches that would serve in the long term.

Accelerating such research now will place us in a better prepared and informed state to finish the fight against COVID-19, but also to better prepare us against future pandemics.

Above: Examples of biosensors and components on a graphene platform

Feature article in Materials World magazine (April, 2021) in the Institute of Materials, Minerals and Mining (APRIL 2021 MATERIALS WORLD | 45)

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