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Graphene Flagship FAQ

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About the material

What is graphene? Why is it regarded as such a revolutionary material?
Only one atom-layer thick graphene is the thinnest and strongest material known to man - a million times thinner than a human hair and between 100-300 times stronger than steel. In addition, it is flexible, transparent and a conductor of electricity that outperforms copper as well as a conductor of heat that outperforms all other known materials. Moreover, though transparent, it is so dense that not even helium, the smallest gas atom, can pass through it.

Graphene has been subject to a scientific explosion since the ground breaking experiments in 2004 when Andre Geim and Konstantin Novoselov at the University of Manchester managed to isolate graphene using a piece of scotch tape to peel off layers of graphite. An achievement that was awarded with the Nobel Prize in Physics 2010.

Is graphene the only two-dimensional material?
No. Graphene is only one out of thousands of materials that can in principle be exfoliated down to a single layer. Amongst these are boron nitride, niobium diselenide, magnesium diboride, molybdenum disulphide – which may be exploited to meet the demands of different industries. Sandwich structures (made up of two, three, four or more different layers of such materials) can offer even greater scope, tuned to fit a range of possible applications.

How can graphene be used?
Graphene could have a significant impact across industries and sectors such as electronics, photonics, medicine, aerospace, automotive, energy storage, water desalination, coatings and paints, solar technologies, and communications.

Potential applications for graphene include:

- Light, efficient supercapacitors, faster than standard batteries, as well as novel batteries.
- Light, flexible, shatter-proof touchscreens for wearable technology.
- Electronic components in post-silicon age.
- Modulators and detectors of light.
- Composites, foams and coatings.
- Biomedical implants and sensors.

Graphene research and applications

When will graphene become commercially feasible?
A number of graphene-based and graphene-enhanced products are already on the market, including graphene-based touchscreens, lightweight tennis rackets, skis, bicycle tires, and an anti-theft packaging system. Batteries and supercapacitors appear on the verge of commercial exploitation.

Other devices – including a flexible electrophoretic display for e-book readers - have already reached prototype stage, and further prototypes of graphene-based display devices, such as flexible touch screens, rollable e-paper and foldable OLEDs (optical light-emitting diodes) are likely to be rolled out in the near future. Analogue and digital electronic devices requiring large area, high-quality graphene, are expected to follow between 2020 and 2030. Current projections suggest that optical devices such as photo-detectors and modulators are also 5-10 years down the line. The emerging research field of graphene based biomedicine is also projected to produce new products for the mainstream healthcare markets within the next 10 years.

How is graphene produced today, and how will it be produced in the future?
Active and focused investigation of graphene started just over 10 years ago, after a simple and effective way to produce relatively large isolated graphene samples was found. Also known as the micromechanical cleavage technique, the ‘Scotch tape method’ has a low barrier to entry in that it does not require large investments or complicated equipment, which has helped considerably to broaden the geography of graphene science.

Today there are several methods of producing graphene that can be extended to industrial scale. For electronics applications, high quality graphene can be grown through a process known as chemical vapour deposition. For bulk applications in nanocomposites or printed electronics, natural graphite can be used to create graphene flakes in solution. Finally, direct chemical synthesis can be used to create small graphene structures with well-defined geometries.

Do specific production methods result in different quality materials?
Yes. Graphene’s beneficial properties come from its symmetrical, honeycomb-like single atomic layer structure. Most graphene has defects, which means its actual strength is likely to be lower than that of a perfect sheet. The larger the sheet, the greater the probability for defects. This increases the importance of manufacturing graphene sheets to exacting standards.

Size is also a factor: the ‘Scotch tape’ method, for example, produces small, high-quality flakes (not enough for most applications) while graphene oxide powder (graphene functionalised with oxygen and hydrogen) yields larger, but more defective material.

However, it is important to note that the material with fewer defects is not always the best for certain applications. So, for example, the production of graphene flakes in solution is not only a cost-effective and scalable method, but it is also the ideal production method for applications in composites, foams, inks, batteries and supercapacitors. Mechanical and chemical ‘defects’ can also be advantageous for certain applications, such as mechanical composites.

Can graphene be dangerous in terms of health and safety?
No specific diseases relating to exposure to engineered nanomaterials have been identified. However, research both within and outside the Graphene Flagship is ongoing and expected to provide answers to such questions as:

- Do tiny graphene flakes pose risk at cellular level?
- How can we guarantee safe disposal of graphene after its useful lifetime has expired?
- What are the risks of the toxic compounds required in some industrial production methods?

For this reason, risk management is a key part of the Graphene Flagship’s brief. Around 5.5 per cent of the flagship’s total budget is invested in research into health, safety and environment. In continuing support of this work the Graphene Flagship expanded its programme in early 2016 to include a work-package on Biological Technologies.

In the Health and the Environment work package, careful assessment of graphene’s potential toxicities at cellular, tissue and organ level and in living systems (plants and amphibians) is a key focus. Specifically, the work package is charged with “focusing on thorough exploration of the biological responses and potential toxicity and eco-toxicity of graphene, taking into account the physico-chemical properties of graphene and the impact of those properties on the interactions with biological systems”.

Unlike previous industrial risks, the study of potential risks from graphene and related materials is being integrated into research programs at every level, with the aim to engineer out risks; essentially performing ‘safety by design’, prior to industrial scale production.

This approach is enshrined in the European Commission’s “Towards a European Strategy for Nanotechnology” (2004), which states: “Scientific investigation and assessment of possible health or environmental risks associated with nanotechnology need to accompany R&D and technological progress.”

Current health and environmental impact research into graphene and related materials builds on a wealth of knowledge from previous research on the subject of nanosafety. For example, in 2010, a joint European/US study found carbon nanotubes did not behave like asbestos fibres.

Instead, the human immune system is capable of degrading nanotubes through an enzymatic reaction. Using this research as a base, the Graphene Flagship is studying whether graphene and its derivatives can indeed be bio-degraded.

About the Graphene Flagship

What is the Graphene Flagship?
The Graphene Flagship is the EU’s biggest ever research initiative and was launched in 2013. With a budget of €1 billion, it represents a new form of joint, coordinated research initiative on an unprecedented scale.

Through a combined academic-industrial consortium, the research effort covers the entire value chain, from materials production to components and system integration, and targets a number of specific goals that exploit the unique properties of graphene.

What is the unifying goal of the Graphene Flagship?
The Graphene Flagship is tasked with bringing together academic and industrial researchers to take graphene from the realm of academic laboratories into European society in the space of ten years, thus generating economic growth, new jobs and new opportunities for Europeans as both investors and employees.

What is a Future and Emerging Technology Flagship?
In 2009, the European Commission identified the need for Europe to address the big scientific and technological challenges of the age through long-term, multidisciplinary R&D efforts. One of the first European Future and Emerging Technology (FET) Flagships, the Graphene Flagship was founded in October 2013.

The Graphene Flagship was initially implemented as a Seventh Framework Programme under the auspices of the European Commission’s Directorate General for Communications Networks, Content and Technology (DG Connect). Now the consortium will fall under FP7's successor research and innovation framework, Horizon 2020. A second FET Flagship, The Human Brain Project, is charged with revolutionizing the future of neuroscience.

What is the Graphene Flagship consortium? How many partners are included in the consortium?

The Graphene Flagship coordinates over 150 academic and industrial groups in 23 European countries. Examples of academic partners include the universities of Manchester and Cambridge in the UK, the Max Planck Society in Germany, CEA and CNRS in France, CSIC in Spain and CNR and IIT in Italy. Examples of industrial partners include large companies such as Nokia, Airbus, Philips and ST Microelectronics, and SME's such as Graphenea. Industrial partners make up about one third of the total Flagship partners. The Graphene Flagship also has a number of associated members as well as partnering projects. A complete list of partners and associated members is available at the Graphene Flagship website.

How is the flagship organised?

The Graphene Flagship is coordinated by Chalmers University of Technology based in Gothenburg, Sweden and its director is Professor Jari Kinaret.

The operative management is handled by the Director and a Management Panel while strategic decisions are taken by the Executive Board which includes the members of the management panel and ten members elected by the General Assembly of all Graphene Flagship partners.

The Strategic Advisory Council consists of world-renowned scientific and industrial experts, including four Nobel laureates. Its key tasks are to advise on strategic research decisions and issues pertaining to handling and protection of intellectual property whilst also facilitating contacts to related national and international research programs and acting as ambassadors for the Graphene Flagship

The Graphene Flagship is divided into 20 work packages grouped into four scientific divisions and a fifth division housing partnering projects. The sixth division is devoted to administration and service functions.

1. Enabling Science and Materials
    1. Enabling Research
    2. Spintronics
    3. Enabling Materials

2. Health, Medicine and Sensors
    4. Health and Environment
    5. Biomedical Technologies
    6. Sensors

3. Electronics and Photonics Integration
    7. Electronic Devices
    8. Photonics and Optoelectronics Applications
    9. Flexible Electronics
    10. Wafer-Scale System Integrations

4. Energy, Composites and Production
    11. Energy Generation
    12. Energy Storage
    13. Functional Foams and Coatings
    14. Polymer Composites
    15. Production

5. Partnering Division

6. Administration and Services
    16. Innovation
    17. Dissemination
    18. Management
    19. Research Management
    20. Alignment

What is the funding system of the programme and how is it divided?
The Graphene Flagship is divided into two separate phases: a 30-month ramp-up phase under the 7th Framework Program (October 1, 2013-March 31, 2016) with a total European Commission funding of €54 million, and a steady state phase under the Horizon 2020 Program (H2020, April 1, 2016-) with expected European Commission funding of €50 million per year.

During the FP7 phase the flagship was implemented as a combination of two instruments, a Collaborative Project, Coordination and Support Action (CP-CSA), and a European Research Area Network Plus (ERANET+), while in H2020 the flagship is being implemented as a single instrument. In FP7, the CP-CSA was funded by the EC according to standard FP7 financing schemes, and the ERANET+ was funded jointly by the EC and the member state funding organisations. In H2020, the single instrument is being funded jointly by the EC and the member states.