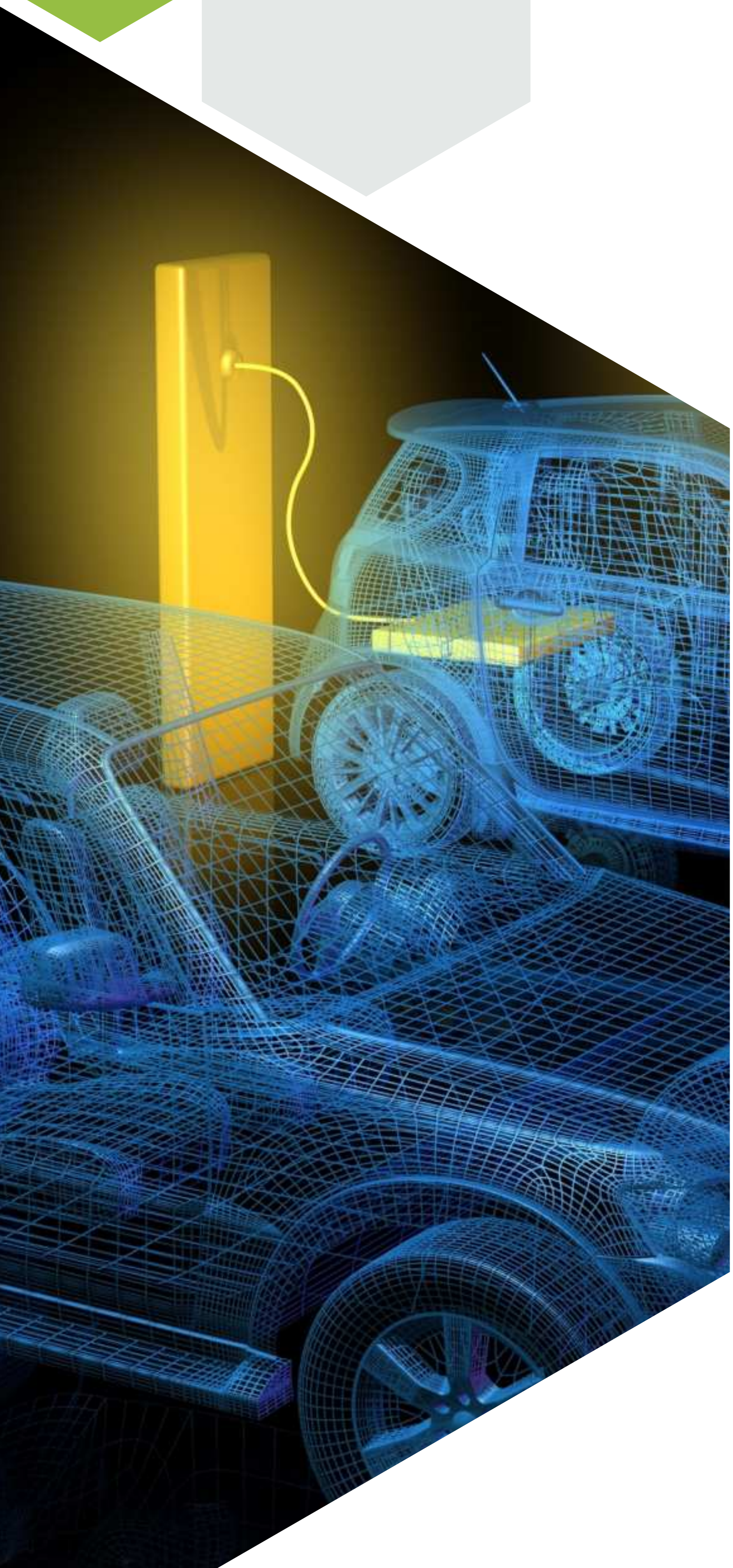
Executive Brief



first graphene

The world's leading graphene company

Graphene-based supercapacitors for next-generation energy storage

Demand for energy storage

In today's increasingly electrified and wirelessly connected world, the demand for highly efficient energy storage solutions continues to grow. Electric vehicles, for instance, will be used for future mobility and logistics networks, but current consumer adoption is limited by 'range anxiety' associated with the use of lithium-ion batteries and the extended times they require to be recharged. Lithium-ion batteries provide high energy-densities, but there are increasing concerns over their incremental pace of their improvement and potential shortages of raw materials for their production.

Supercapacitors are a promising supplement to lithium-ion batteries, offering significantly high power-densities, resilience to multiple charge/discharge cycles and short charging times. Supercapacitors also work in very low temperatures, where conventional batteries often struggle.

Supercapacitors are already used to harvest power from regenerative braking systems and release power to help hybrid buses accelerate, provide cranking power and voltage stabilisation in automotive start/stop systems, assist in train acceleration, open aircraft doors in the event of power failures, capture energy and provide burst power to assist in lifting operations, and provide energy to data centres in the event of power failures. In future, they could be used to power handheld electronic devices and wearable technologies.

As such, the market for these devices is predicted to boom.

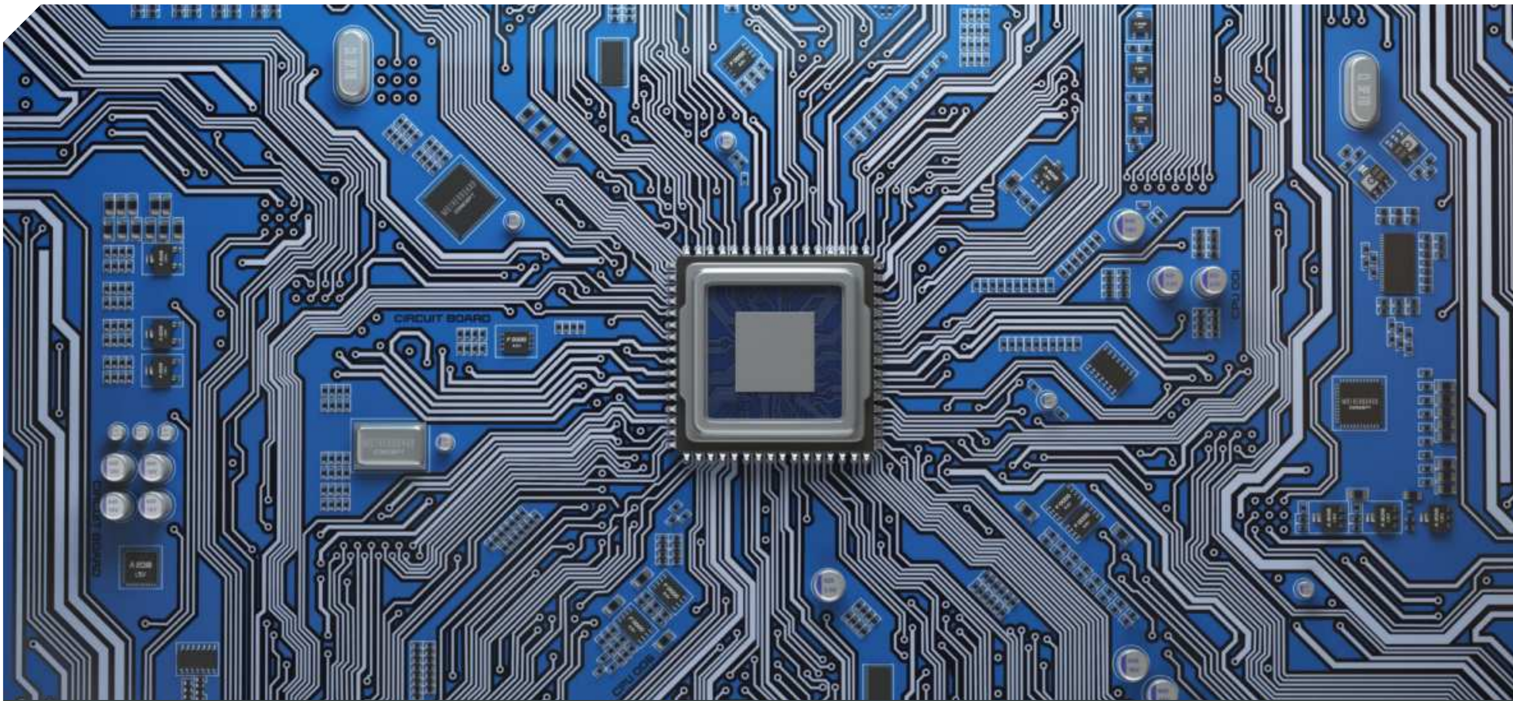
The advantages of graphene

Graphene is a tightly packed layer of carbon atoms, which are bonded together in a hexagonal honeycomb lattice. The material was first isolated and characterised by University of Manchester Professors Andre Geim and Konstantin Novoselov in 2004.

At just one atom in thickness, graphene is the thinnest material known. It is 200-times stronger than steel. It demonstrates an electrical conductivity one million times that of copper. It outperforms diamond in terms of its thermal conductivity, is impermeable even to helium atoms, can stretch to up to 20% of its length and is highly transparent to light.

Graphene has a surface area even larger than that of the activated carbon used to coat the plates of traditional supercapacitors, enabling better electrostatic charge storage. Graphene-based supercapacitors can store almost as much energy as lithium-ion batteries, charge and discharge in seconds and maintain these properties through tens of thousands of charging cycles.

In addition, graphene-based supercapacitors would be lighter, more deformable (an important property for applications such as wearable technologies) and can be stronger than their counterparts based on activated carbon.



How supercapacitors work

The market for supercapacitor devices is forecast to grow at 20% per year to approximately US$2.1 billion by 2022.

Capacitors use static electricity (electrostatics) rather than chemicals to store energy. Conventional capacitors comprise a dielectric sandwiched between two electrically conducting metal plates. Positive and negative electrical charges build up on the plates and the separation between them, which prevents them coming into contact, enables energy to be stored.

Capacitors have many advantages over batteries: they weigh less, generally do not contain harmful chemicals or toxic metals, and they can be rapidly charged and discharged many times without wearing out, due to their high-power density. Weight for weight, however, their basic design prevents them from storing the same amount of electrical energy as batteries as they have a lower energy density.

A supercapacitor differs from an ordinary capacitor in two important ways: its plates are typically coated with activated carbon, which gives them a much larger surface area, and are soaked in an electrolyte, and the distance between them is much smaller, as the separator employed is thinner and functions in a different way.

When the plates are charged, an opposite charge forms on either side of the separator, creating what is called an electric double-layer of maybe just one molecule in thickness. The combination of plates with a larger, effective surface area and the reduction in distance between them yields a capacitor with much greater potential to store energy than conventional alternatives.

Growth in the supercapacitor market may, however, be stifled by the limited energy density of current materials. Graphene-based materials are a highly suitable alternative to these technologies.

Making the advantage count

Now, researchers at the University of Manchester and First Graphene have formed a partnership with the aim of utilising the benefits that graphene can provide by using a scalable process to manufacture new, high-performing hybrid materials.

University of Manchester Professors Robert Dryfe and Ian Kinloch have developed an electrochemical process that enables the production of microporous, metal oxide-decorated graphene materials from graphite. These hybrid materials demonstrate a gravimetric capacitance of up to 500 Farads per gramme (1). Conventional activated carbon has a gravimetric capacitance of 50–150 Farads per gramme[1].

First Graphene, meanwhile, has a proven track record of commercialising advanced nanomaterials. The company has developed an electrochemical process that enables the tonnage-scale manufacture of pristine, high-aspect-ratio platelets of graphene with a typical thickness of 5-10 carbon layers. These have high levels of purity, featuring less than 0.3% w/w total metals and fewer than one-part-per-million of silicon contaminants. Through the use of sophisticated finishing steps, the lateral sizes of the nanoplatelets (called PureGRAPH®) can be carefully controlled, to 5 μm, 10 μm and 20 μm. These can be used to significantly enhance the mechanical, thermal and electrical properties of paints, coatings, polymers and composites.

The hybrid graphene materials that First Graphene will mass-produce will significantly increase the performance of supercapacitors in a wide range of applications, as well as increasing the available supply of materials for their production.

Scale-up of the hybrid graphene materials has been demonstrated at a multi-kilogram level and First Graphene is now engaging with device builders to manufacture and test initial supercapacitor devices.

The potential market for supercapacitors is poised to explode. First Graphene and the University of Manchester will be at the forefront of efforts to commercialise high-performing, next-generation variants based on graphene materials.

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[1] Andinet Ejigu* Kazunori Fujisawa, Ben F. Spencer, Bin Wang, Mauricio Terrones, Ian A. Kinloch, and Robert A. W. Dryfe*Adv. Funct. Mater. 2018, 28, 1804357

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