Graphene: The building block for sustainable cities

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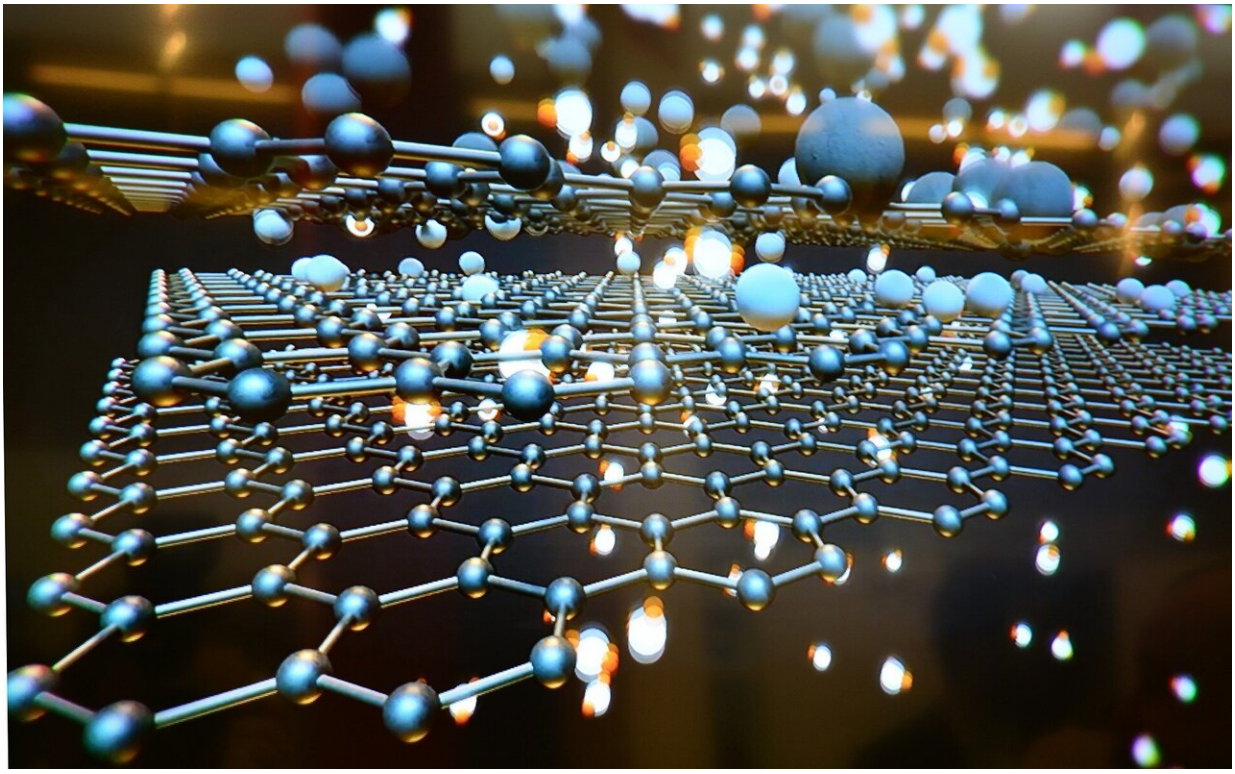

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Innovation in advanced materials offers the disruptive potential to transform the way we build our future cities—and make them greener and smarter.

Construction is associated with the so-called Foundation Industries—which span the cement glass, ceramics, metals, paper and bulk chemicals sectors—which in total produce 28 million tons of materials per year and account for up to 10 percent of the UK's total CO_2 emissions.

If we consider the Climate Change Act (2008) and the UK government's call to reduce carbon emissions to 80 percent below the levels that were seen in 1990 by 2050 then clearly this sector is an obvious focus for a new approach. Innovation in new materials will greatly help city planners, developers and builders to construct a zero-carbon world from the foundations up.

Reducing concrete emissions

An obvious candidate is putting graphene in concrete. According to Chatham House, the international affairs institute, the global production of cement—the 'glue' that holds concrete together—accounts for a staggering eight percent of the world's CO_2 production.

Recent experiments with graphene enhanced concrete have been really promising. My colleague Adrian Nixon, the editor of the Nixene Journal (an independent publication dedicated to graphene and 2-D materials science news), has conducted a review of the various studies on adding tiny amounts of graphene and graphene oxide to concrete. Adrian's review revealed that the addition of just 0.03 percent graphene powder increased the strength of concrete by a conservative average of 25 percent.

So, bearing in mind cement production's proportion of global CO_2 emissions, it could therefore be argued that by delivering a 25 percent efficiency for concrete production through the addition of graphene, we could in turn see this run through the supply chain and potentially deliver

a two percent reduction in worldwide CO_2 levels. That is an exciting proposition and one that could be debated at great length—but the essential point is this: by adding a modest amount of graphene to a building material such as concrete, we can expect a transformational impact on our environment.

Smarter cities

The idea of improving the sustainability of the materials for building is clearly where we should place huge attention—but another very interesting area that is perhaps overlooked is how we can use the benefits of advanced materials to support smart cities of the future.

Smart cities are seen as a way to make our urban environments much more efficient and greener through the adoption of digital technologies that can, for example, better integrate and manage our utility and energy systems.

However, what if some of this technology was embedded directly into the materials that went into our buildings and infrastructure? The exciting thing about graphene and the wider family of 2-D materials—and the endless combinations of these ultra-thin layers to develop brand new 'designer materials' that collectively I call the 'graphenes'—is their extraordinary multifunctional capability. Such materials would be ideal to develop a new generation of smart infrastructure.

Advanced road networks

As an example, the Graphene Engineering Innovation Centre, the flagship advanced materials accelerator based at The University of Manchester, is currently working on a number of projects with

Highways England, the government company responsible for much of the nation's road network, and Arcadis, a leading global design and consultancy firm for natural and built assets.

We are supporting partners including Arcadis and Highways England in addressing the challenges around construction and the road network. An example might be when electric circuitry needs to be applied to the network, usually underground and the feasibility of developing technology that could be embedded within the road structure itself and laid at the same time as the highway, for example, as an integral part of the structure.

This is still potentially a rapid "make or break" type project and will require a lot of new thinking—but the solution could be within the bitumen or a surface marker, such as the road line.

Could the road itself charge your car?

But what if we could have this multifunctional capability used across all the infrastructure and buildings that make up a town or city? It would transform connectivity and make the very fabric of our built environments responsive and intuitive to our daily needs.

So, we can start to imagine charging points that are be embedded across our road network—and every time an e-car comes to a stop at traffic lights or rests in a parking space it can be charged in situ. If the vehicles of the future were using hybrid energy storage—ie a battery powertrain with a supercapacitor unit—then they could be rapidly charged as their drivers happily go about town. And those batteries and supercapacitors would, of course, feature new materials that enable them to operate far more effectively compared to the energy storage devices we are forced to use today.

Similar advances could be made with sensor technology, which will be critical if cities are to achieve the required connectivity levels needed to become smarter, more efficient and ultimately greener. Graphene and sensors are a natural combination because graphene's large surface-to-volume ratio, unique optical properties, excellent electrical conductivity and mobility and high thermal conductivity can all greatly enhance the functionality of a range of sensors.

Graphene and advanced materials potentially have a huge role to play in making our buildings and infrastructure not only significantly greener but demonstrably smarter. As we look to the meet the climate change challenge and aim to 'build back better', I am convinced we need to explore with more urgency on how advanced materials can provide the building blocks for an exciting new future.

Provided by University of Manchester

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