

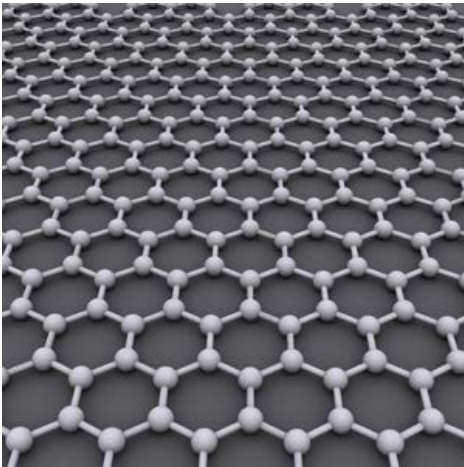
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Question of the Week

When Will Graphene Be Commonly Used?

Practical applications are coming—but slowly.

By Katherine Bourzac on April 8, 2015



A model of the structure of graphene.

If you read much science and technology news, you may come away with the impression that graphene is good at everything. Graphene, a form of carbon that is just one atom thick, does have truly superlative electronic, [optical](#), and mechanical properties. But some applications envisioned for graphene, such as in computers, are appearing to be unrealistic. Nonetheless, the material may become a key component in flexible electronic displays, high-energy batteries, and other products.

Super speedy electronics

In 2004, University of Manchester researchers led by [Andrei Geim](#) and [Konstantin Novoselov](#) were the first

to isolate graphene and test its electrical properties ([pdf](#)). They made graphene by crushing small bits of graphite and peeling away at it with adhesive tape, layer by layer, until they had single-atom-thick meshes of carbon. For this work, the pair won the [2010 Nobel Prize in Physics](#). Graphene, they and others have found, is weird. It exhibits what's called ballistic conduction: electrical charge moves through the material unimpeded—much faster than in silicon, the material used to make today's integrated circuits.

Early on, researchers were very excited about the possibility of graphene computing. But don't expect to find a graphene processor inside your next laptop. Graphene's not a semiconductor, which means it can't be switched from its conductive state to an insulating state without researchers doing a lot of tinkering and babying of the material. Without a strong "off" state to match their "on,"

graphene switches are unlikely to replace silicon in digital logic.

Graphene's electrical properties are far better suited to analog circuits, the kind used in telecommunications. For example, in 2011 IBM demonstrated speedy [graphene circuits](#) of the type used in telecom applications.

Strong stuff

Some of graphene's best properties are mechanical. It's flexible and stretchy. In 2008, researchers at Columbia University showed that graphene was the [strongest material ever tested](#). Researchers at the University of Texas at Dallas, led by [Ray Baughman](#), have been working to take advantage of this combination of strength, flexibility, and high conductivity in [graphene textiles](#). Graphene yarns can be made into artificial muscles or combined with battery materials to power wearable electronics. [This paper explains one possible design](#).

An important milestone to commercializing graphene was to get beyond the so-called Scotch tape method used to make high-quality but small flakes of graphene one at a time. In 2013, researchers led by [Rodney Ruoff](#) at the University of Texas at Austin grew high-quality graphene over large areas by depositing the carbon from a gas onto sheets of copper under carefully controlled conditions (more information can be found in this [paper](#)). That's important: Only high-quality graphene displays ballistic conduction. In 2014, Samsung showed how it could [grow](#) graphene on an alternate surface, germanium.

Some of Ruoff's colleagues at the University of Texas at Austin built on his graphene growth work to make rugged, flexible telecommunications circuits. These devices are tough enough to drive over with a car and can survive a dip in water. [Deji Akinwande](#) demonstrated these devices in a paper in [2013](#), and has been working with Corning and 3M to scale up production.

Power possibilities

Applications closer to commercialization take advantage of graphene's conductivity and mechanical strength and use it as an electrode material. It can serve as a flexible replacement for indium-tin oxide as a transparent conductive electrode for touch-screen displays, for example. In September 2014, the Cambridge Graphene Center and electronics company [Plastic Logic](#) demonstrated a [flexible display using graphene electrodes](#).

Adding graphene to battery electrodes could make high-energy batteries—which will help cars drive farther and make electronics last longer between charges—more mechanically stable. In 2011, researchers at the University of California, Berkeley, used graphene to [sandwich and stabilize](#) tin battery electrodes. One of those researchers, Yuegang Zhang, subsequently moved his lab to China in the hopes of commercializing this work more quickly. In 2014, his group at the Chinese Academy of Sciences showed that graphene sandwiches stabilize [sulfur electrodes](#).

Researchers at the University of California, Los Angeles, are [exploring](#) whether graphene could be used for energy storage in new kinds of supercapacitors—which would charge much faster than batteries and hold as much power (more information is in [this paper](#).)

The Takeaway:

Geim and Novoselov's pioneering work was published just 11 years ago, and that's

a short time in materials science. Graphene's full impact, in tough flexible electronics and wearable devices, is still years away. In the meantime, expect smaller developments, such as [an upcoming LED light bulb](#) whose filament is coated in graphene to increase its life span and decrease its energy consumption.

Thanks to Ron Waldron for this question. Send yours to questionoftheweek@technologyreview.com.

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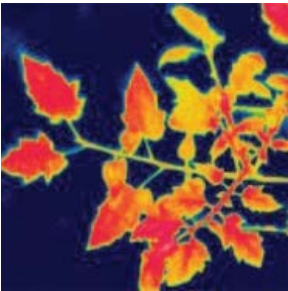
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