How Perfect Can Graphene Be?

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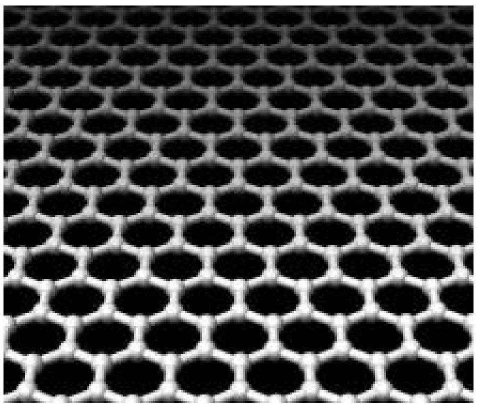

Higher quality samples of graphene are important for exploring the realistic limits of its electronic properties, as well as verifying predictions about graphene's quantum properties. Image credit: Wikimedia Commons.

(PhysOrg.com) -- Physicists have investigated the purest graphene to date, and have found that the material possesses unprecedented high electronic quality. The discovery has raised the bar for this relatively new material, and challenges scientists to find out just how perfect graphene can be.

The team of scientists, Petr Neugebauer, et al, from the Grenoble High Magnetic Field Laboratory in France, has published its study in a recent issue of *Physical Review Letters*, called "How Perfect Can Graphene Be?" The scientists found that their naturally occurring graphene sample possessed a carrier mobility almost two orders of magnitude higher than other types of graphene, and a scattering time that significantly exceeds those reported in any man-made graphene samples. Both properties could open the doors for future developments in graphene technologies.

"The main finding of our paper is definitely the discovery that there exists graphene of exceptionally high quality in nature, much better than man-made specimens prepared by any of current methods, either by exfoliation of bulk graphite or epitaxial growth," coauthor Milan Orlita told *PhysOrg.com*. "The question for the current technology is thus no longer whether the quality of today's specimens can be significantly increased, but instead, how to do it. And it is just the quality of specimens which is, as believed by many researchers, limiting further progress in the physics of graphene."

Experimentally realized for the first time in 2004, graphene consists of a one-atom-thick sheet of carbon atoms arranged in a hexagonal honeycomb lattice, giving it the appearance of chicken wire. Graphene is the basic building block of several other carbon allotropes: for example, graphene sheets stacked together create graphite; rolled up, they make carbon nanotubes; and rolled into a sphere, they become buckyballs. Therefore, finding a more perfect form of graphene could have important implications for many areas of nanotechnology and materials science.

As the physicists explain in their study, there has been a good deal of research in exploring the quantum electrodynamics properties of graphene. However, further progress seems to be limited by the insufficient electronic quality of man-made graphene structures. In addition, graphene's substrate and other surrounding mediums tend to degrade the electronic quality of graphene samples. Higher quality samples are crucial for exploring the realistic limits and quantum phenomena in graphene.

In a study published earlier this year in *Physical Review Letters*, another team of scientists discovered a form of graphene composed of well-defined graphene flakes in the form of sheets located on - yet decoupled from - the surface of bulk graphite (Li, *et al*.). Not only is this graphene well-structured, but the underlying graphite also serves as a well-matched substrate for investigating the graphene layer, which is what the Grenoble scientists do in the current study.

As the scientists explain, the physical mechanism behind the pure graphene's good electronic properties is due to its quantum characteristics - in particular, its well-defined quantization. In experiments, the scientists found that the graphene's Dirac-like electronic states are quantized in magnetic fields down to 1 milliTesla, and they expect the quantization to survive as low as 1 microTesla.

The new measurements of graphene's extremely high carrier mobility set new and surprisingly high limits for graphene's potential properties. The physicists hope that the question of how perfect graphene can be will have an ultimate answer that bodes well for further developments of graphene technologies, although Orlita noted that applications may not come for a while.

"In my opinion, we are still relatively far from real applications of graphene and most of current work on graphene is driven by the fundamental interest," he said. "Nevertheless, just the fundamental research is calling for higher quality samples, as there is a number of phenomena predicted theoretically (e.g. related to the quantum electrodynamics on Dirac fermions), which are still to be experimentally confirmed."

More information: P. Neugebauer, M. Orlita, C. Faugeras, A.-L. Barra, M. Potemski. "How Perfect Can Graphene Be?" Physical Review Letters . 103, 136403 (2009). DOI: 10.1103/PhysRevLett.103.136403