Toward a better understanding of bilayer graphene

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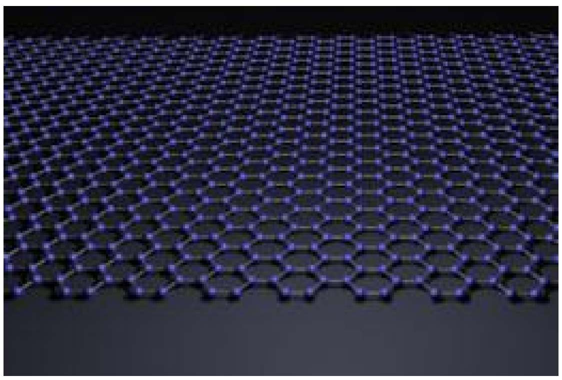

(PhysOrg.com) -- "Graphene is a very exciting material with a number of interesting possibilities, including for use in electronic devices," Pablo Jarillo-Herrero tells *PhysOrg.com*. "However, all graphene systems are electronically different from each other. Single layer graphene has different properties from bilayer graphene, and these have different properties from graphene with more layers. What we want to do is to understand the specific properties of bilayer graphene so that we can learn how to use it for different applications."

Jarillo-Herrero is a scientist at MIT. He worked with Thiti Taychatanapat, at Harvard, to investigate some of the properties of bilayer graphene, and to determine how electronic transport works under certain conditions. Their findings are described in Physical Review

Letters: “Electronic Transport in Dual-Gated Bilayer Graphene at Large Displacement Fields.”

One of the reasons that semiconductors work so well in digital electronics is that they have what is known a band gap. This band gap allows semiconductors to be switched on and off. In order for graphene to work as a viable replacement for these semiconductors, some sort of gap would need to be opened up in the electronic structure.

“It has already been shown that it is possible to open a band gap in bilayer graphene,” Jarillo-Herrero says. “However, the effective electronic transport gap is about 100 times smaller than the theoretical band gap or optical band gap. This difference presents problems. We want to understand the properties of bilayer graphene that make this happen, and how it can be changed.”

Jarillo-Herrero and Taychatanapat offer a systemic look at how the band gap works in bilayer graphene. They found that the band gap is smaller by measuring at low temperatures of less than four degrees Kelvin. “Our studies show that the band gap is still large enough to switch the transistors on and off, but the on/off ratio is only high enough – of order a million – at low temperatures, and we report this for the first time in bilayer graphene,” Jarillo-Herrero says.

However, the main problem is that in order for bilayer graphene to work as a viable semiconductor replacement, it needs to be operable at room temperature. Jarillo-Herrero is hopeful, though. “This is a very important first step that helps us scientifically understand what is happening at low temperatures, and understanding the mechanism that does not permit the electronic transport to work as well at higher temperatures.”

One of the issues, Jarillo-Herrero believes, is that the graphene is usually put on silicon oxide, which introduces electronic disorder. “On silicon oxide, the electrons don't see their full band gap," Jarillo-Herrero explains. "So we try to characterize the disorder and get rid of it. One way to do this is to try putting the graphene on different substrates. When this is done, enormous progress is made. Boron nitride is especially promising, but a number of groups are also trying bilayer graphene on different substrates."

In the end, Jarillo-Herrero hopes that the information learned from this demonstration will help lead to the use of bilayer graphene in digital electronics. "Our work offers a beginning for learning how bilayer graphene transistors operate, and learning about the mobility of electrons in graphene. Hopefully, as we understand the properties of graphene better, we can work toward future integration with electronics and other applications," he says.

"This sort of basic science research is very important," Jarillo-Herrero continues. "Things always have to start at the basic level before we move on, and our work could lead to the use of graphene in electronics."

More information: Thiti Taychatanapat and Pablo Jarillo-Herrero, "Electronic Transport in Dual-Gated Bilayer Graphene at Large Displacement Fields," *Physical Review Letters* (2010). Available online: link.aps.org/doi/10.1103/PhysRevLett.105.166601