Hot nickel nudges graphene: Study simplifies manufacture of semiconducting bilayer graphene

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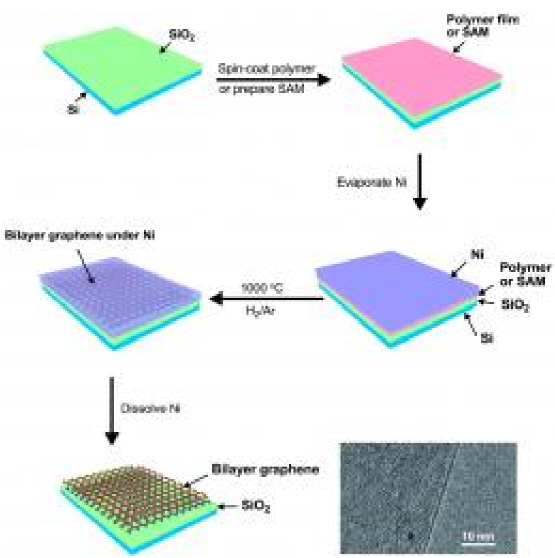

This graphic shows the process of creating bilayer graphene on an insulating substrate, skipping the need to transfer graphene from a metal catalyst. The final image, captured with an electron microscope, clearly shows two layers of graphene produced via the process. (Credit Tour Lab/Rice University)

(PhysOrg.com) -- By heating metal to make graphene, Rice University researchers may warm the hearts of high-tech electronics manufacturers.

The lab of Rice chemist James Tour published two papers this month that advance the science of making high-quality, bilayer graphene. They show how to grow it on a functional substrate by first having it diffuse into a layer of nickel.

Graphene is commonly grown on a metal catalyst, usually copper, and must be transferred to an electrically insulating substrate like silicon dioxide before it can be used in a circuit. The transfer process is cumbersome and time-consuming and can be as frustrating as manipulating household plastic wrap, Tour said.

The new processes outlined in two related *ACS Nano* papers show large-scale bilayer graphene can be grown directly onto a variety of insulating substrates. They eliminate the transfer process and facilitate the growth of large sheets of semiconducting graphene ready for incorporation into patterned transistors, Tour said.

“The ability to grow bilayer graphene directly onto an insulator can permit electronic device manufacturers to build transistors without the industrially burdensome step of placing one sheet of graphene upon another," said Tour, Rice's T.T. and W.F. Chao Chair in Chemistry as well as a professor of mechanical engineering and materials science and of computer science.

Graphene, the single-atom-thick form of carbon, has been the subject of much study since its discovery in 2004. Tour's lab has become a major player in graphene research by publishing in recent years papers on unzipping nanotubes into graphene nanoribbons, characterizing its electrical properties through lithography, creating transparent electrodes for touch screens and making graphene from a variety of cheap sources, even Girl Scout cookies. All aim to cut the cost and complexity of making graphene and bring it into widespread use.

A single layer of graphene, which at the atomic scale looks like chicken wire, is a semimetal and has no bandgap; this makes it unsuitable for many electronic applications. But bilayer graphene is a semiconductor. Its properties depend upon the offset or rotation of the layers in relation to each other and it is tunable using an electric field applied across the layers.

The new processes depend on the solubility of carbon atoms in hot nickel. In one study, a group led by graduate student Zhiwei Peng evaporated a coat of nickel onto silicon dioxide and placed a polymer film -- the carbon source -- on top.

Heating the sandwich to 1,000 degrees Celsius in the presence of flowing argon and hydrogen gas allowed the polymer to diffuse into the metal; upon cooling, graphene formed on the nickel and on the silicon dioxide surfaces. When the nickel and incidental graphene that formed on top were etched away, bilayer graphene was left attached to the silicon dioxide substrate.

In the other study, graduate student Zheng Yan shuffled the sandwich. He topped a layer of silicon dioxide with a sliver of one of a variety of polymers and then put the nickel on top. Again, under high temperature and low pressure, bilayer graphene formed between the silicon dioxide and nickel. Experimentation with other substances revealed that bilayer graphene would also form on hexagonal boron nitride, silicon nitride and sapphire.

“This type of process eliminates the need for roll-to-roll transfer of the graphene to an electronic substrate, because bilayer graphene can now be grown directly upon the substrate of interest,” Tour said.

Authors of the first paper, "Growth of Bilayer Graphene on Insulating Substrates," are Yan, Peng, graduate student Zhengzong Sun, former graduate student Jun Yao, postdoctoral research associates Yu Zhu and Zheng Liu, Tour and Pulickel Ajayan, the Benjamin M. and Mary

Greenwood Anderson Professor in Mechanical Engineering and Materials Science and of chemistry.

Authors of the second paper, "Direct Growth of Bilayer Graphene on SiO2 Substrates by Carbon Diffusion Through Nickel," are Peng, Yan, Sun and Tour.

More information:

Growth of Bilayer Graphene on Insulating Substrates: pubs.acs.org/doi/abs/10.1021/nn202829y

Direct Growth of Bilayer Graphene on SiO2 Substrates by Carbon Diffusion Through Nickel: pubs.acs.org/doi/abs/10.1021/nn202923y

Provided by Rice University

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