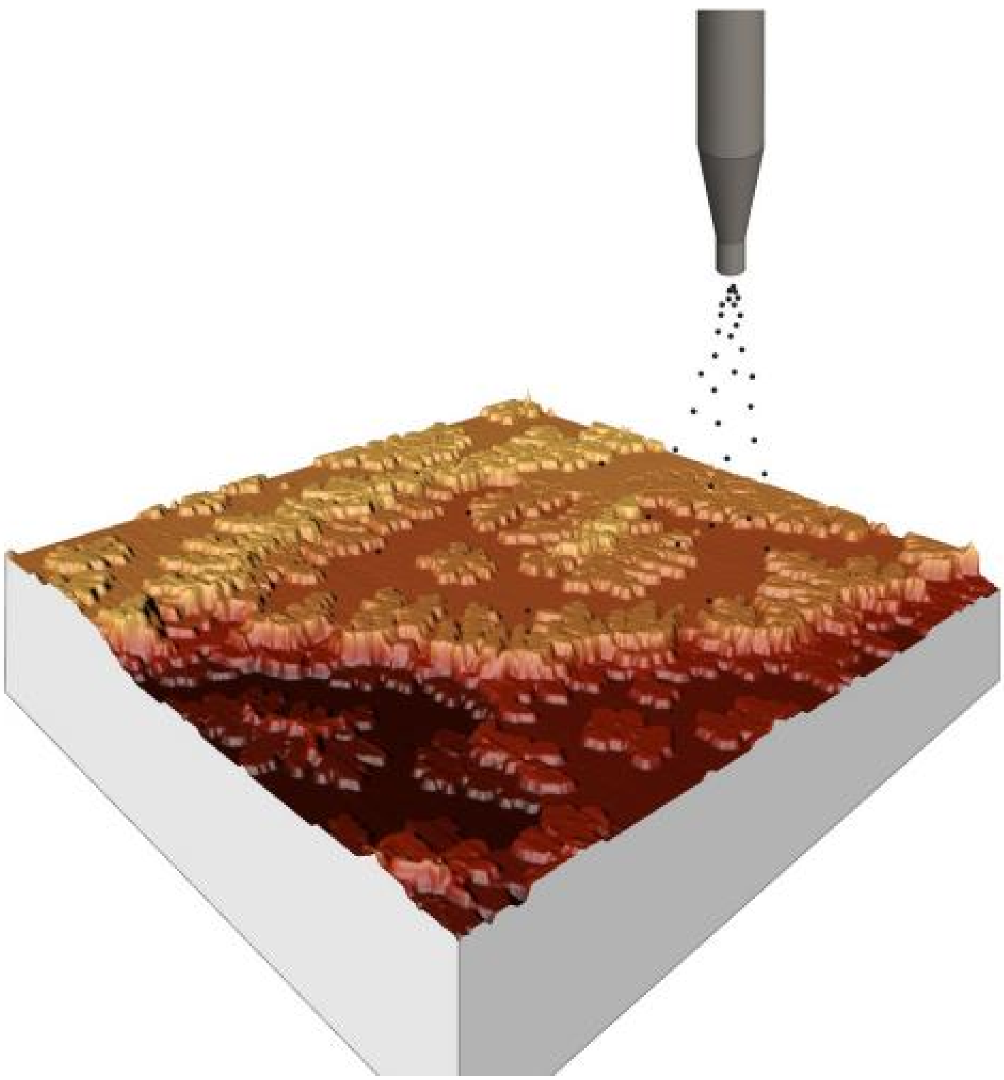
Argonne scientists are first to grow graphene on silver

March 3 2014, by Justin H.s. Breaux



Atomic carbon (black spheres) is evaporated at over 2,300 degrees Celcius and deposited on a silver platform where flakes of graphene form. Lighter-colored regions correspond to graphene growth and silver is depicted in the darker regions.

(Phys.org) —Silver, meet graphene. Super strong, super light, near totally transparent and one of the best conductors of electricity ever discovered, graphene is a one-atom-thick sheet of carbon atoms that owes its amazing properties to being two-dimensional.

Graphene, meet silver. Silver is a high-quality noble metal that corrodes very slowly in moist air and doesn't typically interact chemically with other substances. Graphene, meanwhile, is a sought-after platform for new physics and device applications.

"You have one material, silver, that's really good at confining light and another, graphene, that's really good with efficiently moving electrons," said Northwestern University graduate student Brian Kiraly, who discovered the new process making the growth of graphene on silver possible.

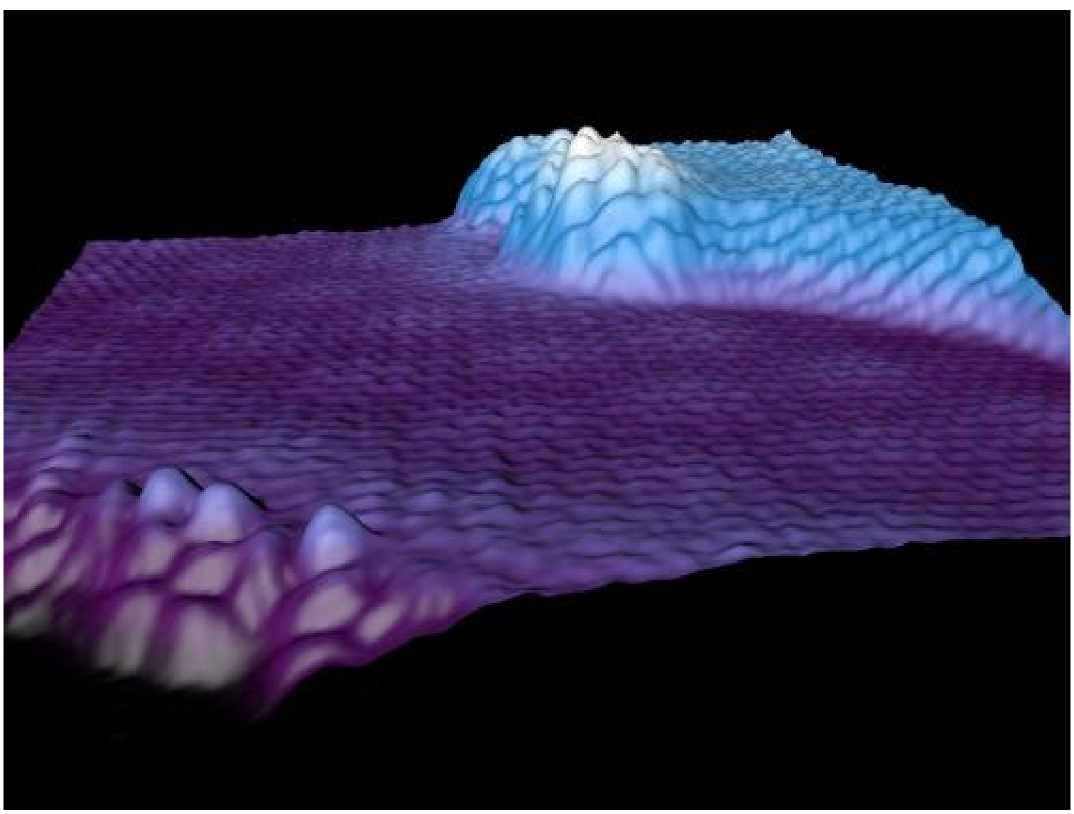
Researchers at Department of Energy's Argonne National Laboratory, in collaboration with scientists at Northwestern Universit, are the first to grow graphene on silver, which until now posed a major challenge to many in the field. Part of the issue has to do with the properties of silver; the other involves the process by which graphene is grown.

Chemical vapor deposition is currently the industry standard for growing graphene. The technique allows hydrocarbons, like methane or ethylene, to decompose onto a hot platform in order to form carbon atoms that become graphene. However, this technique doesn't work with a silver platform.

"The traditional method of decomposing hydrocarbon onto a transition metal wasn't working," said Nathan Guisinger, a staff scientist at Argonne's Center for Nanoscale Materials. "The methane won't break down, it'll just hit the hot silver and bounce off and remain methane, so there's no carbon source to actually grow the graphene."

At this point, to figure out how to grow graphene on silver, the researchers needed to understand the atomic and molecular properties of the material. For instance, atomic carbon evaporates at extremely high temperatures—over 2,400 degrees Celsius—forcing the researchers to account for a number of different parameters to create a layer one atom thick.

Additionally, whereas graphene is conventionally grown at temperatures of 1,000 degrees C or above, the new Argonne-Northwestern technique grows it at a lower temperature of 750 degrees, giving researchers more options for working with the material. This method also slows down the process to determine the right growth rate and distribution for a single layer of carbon atoms landing on the silver.



A three-dimensional rendering of graphene showing continuous growth on a platform. Lighter colors correspond to slightly higher relative positions. Waves depict the bonds between carbon atoms in the honeycomb lattice.

The first step in growing the graphene layer was making sure the silver substrate was "atomically clean"—a hard standard to meet.

"It's very difficult to make an atomically clean platform," Guisinger said. "Almost all platforms exposed to air will get covered with a water layer and oxidize." To prevent this phenomenon from occurring, the researchers work in a specially designed ultra-high vacuum environment.

To initially clean the platform, Kiraly used a technique called "sputter annealing." This is where the platform used to grow the graphene is sprayed with ions that chew up the surface and rids it of any organic or inorganic material. The next step is to anneal the metal, a process "that heals it and allows for atomically clean and flat surfaces," said Kiraly.

After a series of examinations, the researchers discovered that they had successfully deposited a single layer of graphene on silver.

Encouraged by this result, the researchers hope to demonstrate how to layer graphene with other one-atom-thick materials, such as silicene, into stacked atomic layers to create hybrid materials.

Because of silver's excellent optical properties, Kiraly envisions this research having applications in detectors.

"Conventionally, you can make things with both optical and electronic components to them, as in opto-electronics devices," said Kiraly.

"Anything like a photo-detector or a solar cell has some type of light interaction that corresponds with an electronic effect or vice versa."

There is increased interest in moving graphene from the lab to into lighter, more energy-efficient consumer devices. The University of Manchester in England, for example, will finish their National Graphene Institute next year to the tune of £61 million.

"With the discovery of how to make graphene, now there's a hunt for more two-dimensional materials. Once they're discovered, we want to know how to combine them," said Guisinger.

But for now, it is up to scientists like Guisinger and Kiraly to figure out how those atom-sized pieces fit together to create the next technological breakthroughs.

The work is outlined in a paper, "Solid-source growth and atomic-scale characterization of graphene on Ag(111)", published in the journal *Nature Communications*.

More information: "Solid-source growth and atomic-scale characterization of graphene on Ag(111)." Brian Kiraly, Erin V. Iski, Andrew J. Mannix, Brandon L. Fisher, Mark C. Hersam, Nathan P. Guisinger. *Nature Communications* 4, Article number: 2804 DOI: 10.1038/ncomms3804. Received 28 May 2013 Accepted 22 October 2013 Published 15 November 2013

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