Scientists prove graphene's edge structure affects electronic properties

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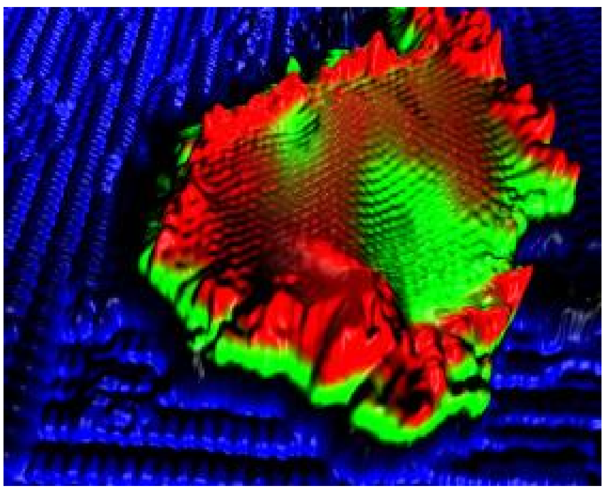

Atomic resolution scanning tunneling microscope image of a nanometer scale piece of graphene on silicon. Photo courtesy Joseph Lyding

(PhysOrg.com) -- Graphene, a single-atom-thick sheet of carbon, holds remarkable promise for future nanoelectronics applications. Whether graphene actually cuts it in industry, however, depends upon how graphene is cut, say researchers at the University of Illinois.

Graphene consists of a hexagonal lattice of carbon atoms. While scientists have predicted that the orientation of atoms along the edges of the lattice would affect the material's electronic properties, the prediction had not been proven experimentally.

Now, researchers at the U. of I. say they have proof.

"Our experimental results show, without a doubt, that the crystallographic orientation of the graphene edges significantly influences the electronic properties," said Joseph Lyding, a professor electrical and computer engineering. "To utilize nanometer-size pieces of graphene in future nanoelectronics, atomically precise control of the geometry of these structures will be required."

Lyding and graduate student Kyle Ritter (now at Micron Technology Inc. in Boise, Idaho) report their findings in a paper accepted for publication in *Nature Materials*. The paper is to be posted on the journal's Web site on Sunday (Feb. 15).

To carry out their work, the researchers developed a method for cutting and depositing nanometer-size bits of graphene on atomically clean semiconductor surfaces like silicon.

Then they used a scanning tunneling microscope to probe the electronic structure of the graphene with atomic-scale resolution.

"From this emerged a clear picture that edges with so-called zigzag orientation exhibited a strong edge state, whereas edges with armchair orientation did not," said Lyding, who also is affiliated with the university's Beckman Institute and the Micro and Nanotechnology Laboratory.

"We found that pieces of graphene smaller than about 10 nanometers with predominately zigzag edges exhibited metallic behavior rather than the semiconducting behavior expected from size alone," Lyding said. "This has major implications in that semiconducting behavior is mandatory for transistor fabrication."

Unlike carbon nanotubes, graphene is a flat sheet, and therefore compatible with conventional fabrication processes used by today's chipmakers. But, based on the researchers' experimental results, controlled engineering of the graphene edge structure will be required for obtaining uniform performance among graphene-based nanoelectronic devices.

"Even a tiny section of zigzag orientation on a 5-nanometer piece of graphene will change the material from a semiconductor into a metal," Lyding said. "And a transistor based on that, will not work. Period."

Provided by University of Illinois at Urbana-Champaign

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