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Pencils point way to novel nanocircuits

Edited by Lawrence Kren

Graphite, the material in pencils, could form the basis for a new class of nanoscale electronic devices. Using thin layers of graphite called graphene, researchers at the Georgia Institute of Technology and the Centre National de la Recherche Scientifique (CNRS) in France have built proof-of-principle transistors, loop devices, and other circuitry.

A proof-of-principle device made of graphene.

Graphene is essentially a carbon nanotube rolled flat into a ribbon. Ribbon width controls the material's band gap and is responsible for confining electrons through a quantum effect similar to that seen in nanotubes. Narrow ribbons have all the special properties of nanotubes, such as ultralow electrical resistance.

In the lab, researchers heat a siliconcarbide wafer in a high-vacuum to drive silicon atoms from the surface, leaving behind a thin, continuous-graphene layer. Next, they spin-coat onto the surface a photoresist material of the kind used in semiconductor fab. Conventional optical or electron-beam lithography techniques produce patterns on the surface, which are then chemically etched to remove unwanted graphene. Electron-beam lithography creates feature sizes down to 80 nm, eight times larger than the current 10-nm target. Eventually, the group hopes to fashion graphene layers less than 10 atoms thick. Systems using the material would manipulate electrons as waves rather than particles, much like photonic systems control light waves.

So far, they have built an all-graphene planar field-effect transistor. Applying voltage to the side-gated device produces a change in resistance through its channel. However, this first device had a substantial current leak, which the team expects to eliminate with minor processing adjustments.

The researchers have also built a working quantum-interference device, a ringshaped structure that would be useful in manipulating electronic waves. Graphene could as well be the foundation for molecular electronics, helping resolve thorny resistance issues, and may act as a conduit to conventional silicon-based systems.

However, "It's a big advantage to make systems out of one continuous material, compared to having different materials with different interfaces, and large resistances that cause heating at the contacts," says Walt de Heer, a professor in Georgia Tech's School of Physics. "Our ultimate goal is integrated electronic structures that work on diffraction rather than diffusion of electrons. This will allow the production of extremely small devices with high efficiencies and low power consumption."

Funding for the work comes from the National Science Foundation and **Intel**.

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