Nano Focus

Electron clouds distortion on graphene surface harm conductivity

Graphene, which comprises a single layer of carbon atoms linked in a honeycomb-like arrangement, is highly conductive. However, a research team has produced a series of images that reveal how folds and ripples in this material can limit its conductivity. Under ideal circumstances, when graphene is completely flat, electric charges speed through it without encountering many obstacles, said Sarbajit Banerjee of the State University of New York, Buffalo, one of the researchers who published the study in the June 28 online edition of *Nature Communications* (DOI: 10.1038/ncomms1376). However conditions are not always optimal.

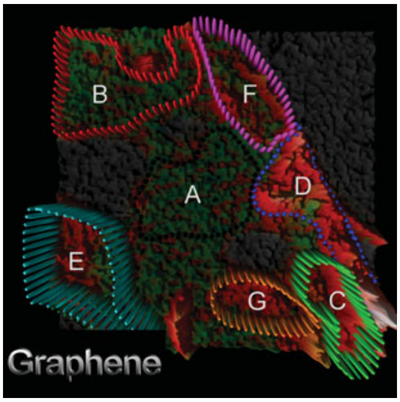
The images demonstrate that when graphene is folded or bent, the electron cloud lining its surface also becomes distorted. This makes it more difficult for an electric charge to travel through.

Banerjee, D.A. Fischer of the National Institute of Standards and Technology, P.S. Lysaght of SEMATECH, D. Prendergast of the Lawrence Berkeley National Laboratory, and their colleagues used scanning transmission x-ray microscopy and near edge x-ray absorption fine structure (NEXAFS) to create the images, and the experiments were further supported by computer simulations.

"Using simulations, we can better understand the measurements our colleagues made using x-rays, and better predict how subtle changes in the structure of graphene affect its electronic properties," said Prendergast. "We saw that regions of graphene sloped at different angles, like looking down onto the slanted roofs of many houses packed close together."

Besides documenting how folds in graphene distort its electron cloud, the research team also discovered that contaminants that cling to graphene during processing linger in valleys created in the material where it is uneven. Such contaminants uniquely distort the electron cloud, thereby changing the strength with which the cloud is bound to the underlying atoms.

"It's not well understood how to transfer graphene onto substrata without it folding onto itself," Banerjee said. The study suggests that companies hoping to incorporate graphene into products such as conductive inks, ultrafast transistors, and solar panels could benefit from more basic research on the nanomaterial. Improved processes for transferring flat sheets of graphene onto commercial products could greatly increase the efficiency of those materials.

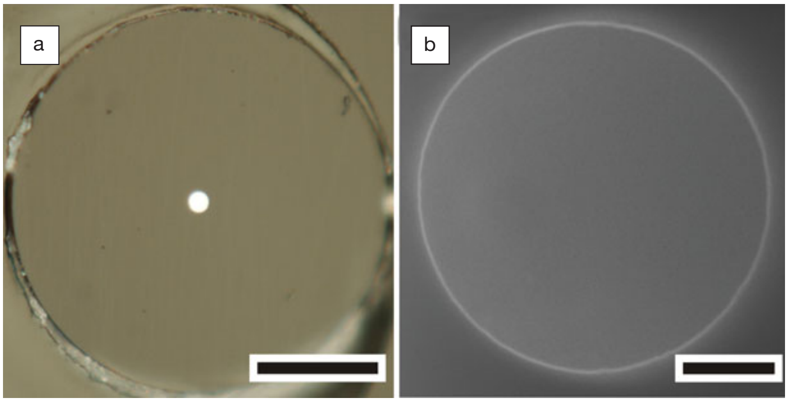


Imaging electronic domains in graphene: Dotted lines show distinctive regions of graphene that are sloped at different angles. Soft x-rays paint a bird's-eye view of the electron cloud of graphene. The image is 4 μm × 4 μm. *Photo Credit*: Brian J. Schultz.

Atomically smooth polycrystalline silicon waveguides fabricated

Atomically smooth optical fibers made of polycrystalline silicon are advancing microscale optoelectronics. In the July 1 issue of *Optics Letters* (DOI:10.1364/OL.36.002480; p. 2480), N. Healy of the University of Southampton, F.R. Sparks of Pennsylvania State University, and their colleagues detail their process for creating optical waveguides with an unprecedentedly low level of surface scattering.

The research team used 500°C silane and helium gas to deposit silicon in the pores of 5.6 μm and 1.3 μm internal diameter silica capillaries before annealing the constructs at 1325°C. The resulting waveguides possessed a surface roughness of σ = 0.1 nm RMS with *z*-direction resolution of 0.01 nm RMS. This surface roughness is an order of magnitude less than what has been previously measured in polycrystalline waveguides, and is also lower than that of a competing fabrication process, etchless silicon-on-insulator. The high



(a) Optical microscope image of the 5.6 μm polysilicon core fiber as prepared for optical coupling, scale bar 50 μm. (b) Helium ion microscope image of the 1.3 μm core, scale bar 400 nm. Reproduced with permission from *Opt. Lett*. **36**(13)v(2011), DOI:10.1364/OL.36.002480; p. 2480. © 2011 Optical Society of America.

https://doi.org/10.1557/mrs.2011.187 Published online by Cambridge University Press

degree of smoothness reduces surface scattering at the fiber-cladding interface, reducing scattering-based transmission loss to negligible levels.

Further measuring transmission losses over an extended telecom wavelength band, the researchers suggest the resulting λ^{-4} dependence is associated with Rayleigh scattering in the bulk. By optimizing the annealing process, scientists could create inexpensive optical waveguides with less loss than currently available materials, according to the research team.

Polycrystalline silicon is an attractive material to use for optoelectronics and these advances only make it more so. In addition to their low cost, polycrystalline waveguides are easily integrated vertically on-chip and retain some of the electronic functionality of crystalline silicon. New, loss-minimized waveguides using this method could open the door to faster, more capable fiber communication devices.

Benjamin Scheiner

In Memoriam:

Robert L. Fleischer

Robert L. Fleischer, Research Professor of Geology at Union College, died of complications of cardiac amyloidosis on March 3, 2011 at the age of 80. He was well known for developing and applying the technique used for nuclear-track etching, and for explaining how small additions of elements strengthen pure solids.

Fleischer earned AB, AM, and PhD degrees at Harvard University in applied physics. He then became Assistant Professor of Metallurgy at the Massachusetts Institute of Technology (1956–1960), before moving to General Electric Research Laboratory in Schenectady, New York, during what he referred to as the "Golden Age" of research, where he remained until 1992. Following his time at General Electric, Fleischer was Research Professor of Earth and Environmental Sciences at Rensselaer Polytechnic Institute 1992–1997 and then joined Union College's Geology Department in 1997, where he stayed for the rest of his career.

One of Fleischer's great joys was learning about new areas of research, ones that he had not dreamed of entering. He and his colleagues designed the cosmic ray detector taken to the moon and back by the Apollo 16 astronauts, studied the damaging effects of cosmic rays on moon rocks, and dated meteorites and archeological specimens.

He published over 350 scientific papers and held 19 patents. His track work led to two companies founded by GE (Nuclepore—thin membranes with holes of cleanly specified sizes—and Terradex—radon measuring for home safety or for locating shallow deposits of uranium in the ground). Another commercial development (not commercialized by GE) was neutron radiation monitoring and mineral dating used in oil exploration to sense excessive heating in the earth—heating that would have destroyed any oil that might have been nearby. This use was by far the largest financial success—giving immense savings in wells not drilled.

Some of Fleischer's many awards include the American Nuclear Society's Special Award for Distinguished Service in the Advancement of Nuclear Science (1964), the U.S. Atomic Energy Commission's E.O. Lawrence Award (1971), and NASA's Medal for Exceptional Scientific Achievement (1973). Fleischer was presented with GE's R&D Center's Coolidge Fellowship Award (1972) for sustained technical contributions, and was elected to the National Academy of Engineering and the American Academy of Arts and Sciences. He was a fellow of the American Physical Society, the American Geophysical Union, the Health Physics (radiation protection) Society, the American Association for the Advancement of Science, and the American Society for Metals. He co-authored *Nuclear Tracks in Solids* with Buford Price and Robert Walker, wrote *Tracks to Innovation*, and co-edited book sets on intermetallic compounds with Jack Westbrook.

In 1995, Fleischer served as visiting scientist for *MRS Bulletin*, where he also served as guest editor that year of the December issue on ion tracks in solids. He had continued serving as an advisor for the publication and contributed a "Posterminaries" article in the January 2011 issue.

https://doi.org/10.1557/mrs.2011.187 Published online by Cambridge University Press