"Exposure to flue gas is enhanced to increase the speed of capture with a huge surface area across millions of spheres," says Haszeldine. "Circulation can be reproducible and reliable using normal industrial processes—the same spheres irrespective of contents. The chemical capture filling, simple or toxic, can be changed, tailored, and specified to the application without affecting handling, corrosion, or leakage."

The exterior and interior materials could also be tuned, created with materials that target specific molecules in the gas, such as CO_2. Also important is the fact that the microcapsules can be used multiple times. Tests showed that in 10 absorption-desorption cycles, the capsules maintained a 90% absorption rate. Scaling the process up to an industrially stable level is a next step in making these novel capsules a viable form of carbon capture.

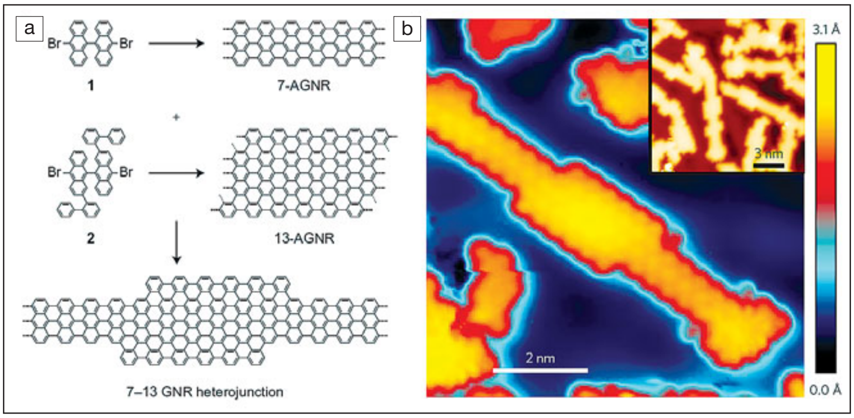
Meg Marquardt

Nano Focus

Bandgap engineering in graphene nanoribbons sets the stage for next-generation electronic devices

Miniaturization of consumer electronics has put pressure on the industry to develop semiconductor devices that operate at smaller length scales. An increase in recent demand coupled with more advanced synthesis techniques has led to breakthroughs in semiconductor design and development. From three-dimensional chip stacking to the fabrication of a junctionless transistor, researchers are making great strides every day to push this industry to the brink of its dimensional limits. However, the shrinking of current semiconductor devices often leads to performance loss. Graphene-based electronics have the potential to outshine current technology with greater scalability, more control over dopants, and higher charge-carrier mobility. Graphene-based electronics would benefit from ballistic electron transport; much like a carefully aimed shot will arrive at its target in the shortest possible time, the scattering of electrons from atomic sites is limited in materials on very small length scales. With the electrons experiencing minimal obstruction, these devices could operate at much faster speeds, leading to improved performance.

Utilizing a novel bottom-up synthesis strategy, researchers from the University of California–Berkeley, Lawrence Berkeley National Laboratory, and the Kavli Energy NanoSciences Institute have fabricated molecular-scale graphene-based heterojunctions with widths less than 1.5 nm. As the researchers describe in their January *Nature Nanotechnology* publication (DOI: 10.1038/NNANO.2014.307), graphene nanoribbon (GNR) heterojunctions were fabricated by combining precision-designed molecular building blocks. By altering the shape of the molecular building blocks, the researchers generated ribbons with nonuniform widths that display position-dependent local densities of states (LDOS).



(a) Synthesis strategy of nonuniform graphene nanoribbon (GNR) heterostructures from basic molecular building blocks. (b) High-resolution scanning tunneling microscope image showing topography of a GNR on a gold surface. Inset: Larger-scale image showing multiple GNRs. AGNR is armchair graphene nanoribbon. Reproduced with permission from *Nature Nanotech.* **10** (2) (2015), DOI: 10.1038/nnano.2014.307; p. 156. © 2015 Macmillan Publishers Limited.

The researchers took a twofold approach when it came to investigating the local electronic structure of these GNRs. First, the researchers used scanning tunneling microscopy to spatially map electron behavior at various points on these ribbons to obtain a picture of the energy-dependent LDOS. They then explained their findings by simulating the electronic structure of the ribbons using first-principles density functional theory within the local density approximation. Both experimental and theoretical results confirmed that controlling the width of the GNRs in subnanometer increments allowed for explicit manipulation of the bandgap, a technique the researchers called "molecular-scale bandgap engineering."

"We can't go on working with silicon" said Felix Fischer, a contributing author to this work. "It might be two or three more generations of silicon chips in the pipeline right now, but even big manufacturers are searching for new alternatives. Whether this is going to be graphene or other types of materials, that's still open for debate. What we're doing is laying the fundamental groundwork." The researchers have demonstrated that the synthesis of GNR structures with enhanced functional effects is possible through the combined efforts of theorists, physicists, and chemists. As Fischer says, "Right now it turns more into kind of a dialogue between experiment and theoretical prediction of what the most exciting material properties are going to be."

Ian J. McDonald

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