

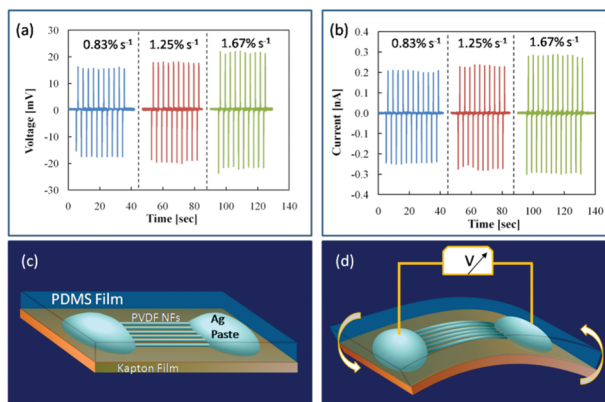
## Scavenging Life's Energy

■ Researchers have made significant headway in large-scale harvesting of energy from renewable sources, such as wind and solar power. However, much of the personal energy we use for walking, typing, speaking, and breathing goes to waste. Recently, various research teams have had some success with harvesting mechanical energy of small motions, such as the beat of a heart, using nanowire-based nanogenerators. Other teams have shown the practicability of harvesting the biochemical energy available in glucose/O<sub>2</sub> in biofluid using a biofuel cell that relies on active enzymes as catalysts.

Seeking to capitalize on these recent advances, Hansen *et al.* (p 3647) created a hybrid nanogenerator that combines a nanogenerator and a biofuel

cell to harvest both mechanical and biochemical energy, either individually or simultaneously. The team's nanogenerator was based on an aligned array of piezoelectric poly(vinylidene fluoride) (PVDF) nanofibers on a Kapton (polyimide)

substrate, encased in polydimethylsiloxane. The biofuel cell was composed of electrodes patterned onto Kapton film topped with multiwalled carbon nanotubes, to which glucose oxidase and lactase molecules were attached to form the anode and cathode. Tests showed that these devices generated voltage and current independently. When the two devices were integrated using a RC high-pass filter, the peak voltage nearly doubled from ~50 to ~95 mV. The researchers showed proof of concept by using the hybrid device to power a ZnO nanowire-based UV light sensor. The authors suggest that these findings demonstrate the potential for a completely self-powered nanosized device for biomedical applications.



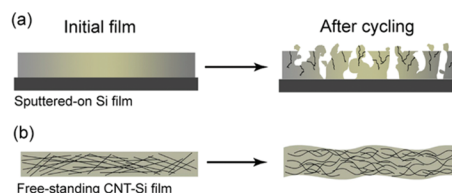
## Reinforcing Structure, Reimproving Function for Lithium Ion Battery Anodes

■ Lithium ion batteries have grown in popularity, evolving from use in laptop computers and cellular phones to power tools and electric cars. Current commercial anodes consist of graphite coated onto a Cu foil current collector, but researchers have been experimenting with a wide variety of other materials to improve energy density. One of the most attractive candidates for anode material is Si because it has the highest known capacity. However, the expansion and contraction of this material during Li cycling pulverizes Si and causes rapid failure. Si nanowires bonded to the current collector have been shown to solve this problem, yet they make the

metal current collector weigh more than the active Si material, compromising the energy density.

To make Si a more viable option, Cui *et al.* (p 3671) developed a novel anode material composed of a composite Si carbon nanotube (CNT) film in which a CNT network is embedded within the Si base much like steel bars in reinforced concrete. The team created free-standing films using either a chemical vapor deposition technique with amorphous silicon or a compositing technique with Si nanoparticles. Tests showed that these films have low resistance, high energy capacity, high specific charge storage capacity, and good

performance even through multiple cycles. Though some cracking and splitting were evident after repeated cycles, the CNTs held the film together. Since the film can act as both an anode and a current collector, the authors suggest that its low weight can increase the specific capacity a factor of 10 compared to current graphite/Cu anodes.



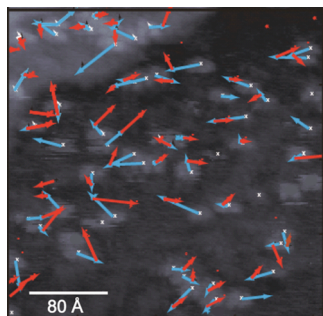
## Ring Around the Molecule

■ Several families of molecules sport interlocking components, including rotaxanes, which resemble dumbbells encircled with a ring too small to slide over the ends. These molecules have been proposed for potential applications ranging from molecule-sized electronics to nanoelectromechanical devices. Though they have been somewhat characterized using solution-phase measurements, little is known about how these functional molecules behave at the single-molecule level in various environments. Rotaxanes' inherent flexibility leads to poorly defined orientations when attached to surfaces, making them difficult to image through microscopy.

To learn more about these potentially useful molecules, Ye *et al.* (p 3697) designed a roxatane molecule with disulfide groups attached to the dumbbell termini as recognition sites and bound at each end

to a Au substrate. Using scanning tunneling microscopy (STM), the researchers were able to track the location of the ring, whose higher electrical conductivity and greater height relative to the dumbbell made it resolvable through STM. The researchers found that increasing the electrochemical potential from +0.12 to +0.53 V, oxidizing the disulfide tetrathiafulvalene

(TTF), caused the ring to move away from the TTF station. Decreasing the potential, which reduced TTF, caused the ring to return to its favored position encircling the TTF station. Such displacements were relatively smaller where rotaxanes were clustered, suggesting that neighboring molecules can impact the ring's motion. Other smaller movements appeared to be due to conformational changes of the flexible dumbbell. The authors suggest that completely rigid dumbbells could lead to more consistent motions of the ring, an important step toward making these bistable molecules work cooperatively.



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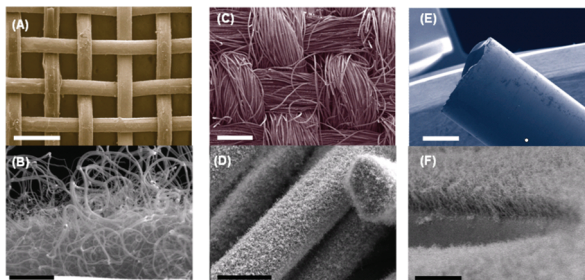
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## Carbon Nanotubes Keep Their Cool

Carbon nanotubes' (CNTs) extraordinary physical, electrical, optical, and thermal properties have made this material desirable for a great number of potential applications. To achieve the vast number of proposed uses for CNTs, growing them on a variety of materials will be essential. Unfortunately, this has proven elusive due to the high temperatures required for growth with current chemical vapor deposition (CVD) methods. Consequently, oxides, nitrides, or highly stable metals have been the most popular substrates used thus far.

Seeking to expand the number of support materials, Magrez *et al.* (p 3702) developed a new approach that relies on the oxidative dehydrogenation reaction of  $C_2H_2$  with  $CO_2$ . The team discovered that this reaction is so efficient that it allows

CNT growth at temperatures below 400 °C. After decorating the surfaces of materi-



als with Fe-based metallic nanoparticles using a co-precipitation process and exposing the materials to their novel CVD method, the researchers observed that the nanoparticles became homogeneously covered with high-quality CNTs. The density

and diameter of the CNTs was tunable with the distribution and size of the support particles. The optimal growth temperature varied with the substrate material, ranging from 400 to 650 °C, but growth at lower yields was still possible at significantly lower temperatures. Using this method, the researchers were able to grow

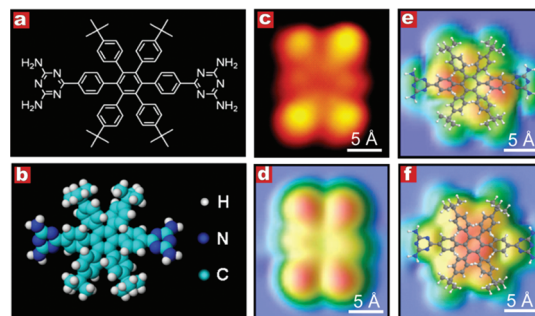
CNTs on a variety of surfaces, including copper mesh, carbon fiber textile, the rim of a Pasteur pipet, a Si wafer, and even a wooden toothpick. The authors suggest that this method could facilitate bringing CNTs' potential applications to fruition.

## "Lander" Molecules Make Giant Leap

Using noncovalent interactions for self-assembly has been widely studied as a technique for creating supramolecular patterns on inorganic solid surfaces—structures expected to have substantial potential applications in nanotechnology and nanodevices. Several one-dimensional (1D) and two-dimensional (2D) hydrogen-bonded structures have now been studied, often using scanning tunneling microscopy (STM). Most of these structures have been planar compounds whose rigid chemical functionalities direct self-assembly. However, some studies have involved "Lander-type" molecules composed of an aromatic backboard with bulky chemical side groups that act as legs, giving these molecules an appearance akin to the Mars lander. Organized 1D Lander structures have been formed and studied, but long-range, ordered 2D structures have thus far been lacking.

Aiming to break new ground in this area, Yu *et al.* (p 4097) synthesized novel Lander molecules based on a hexaphenylbenzene core with four *tert*-butyl groups as legs and equipped with dual diamino-triazine functional groups that interact through hydrogen bonding. The researchers used STM to characterize these "Lander-DAT" molecules. Then, under ultrahigh vacuum conditions, the team adsorbed these molecules into various patterns including 1D chains as well as five different long-range, ordered 2D patterns, including network structures resembling windmills, grids, and stripes. STM image calculations and molecular mechanics structural modeling showed that these distinct patterns rely on two

characteristic types of hydrogen bonding that can take place only in the three-dimensional Lander molecules and are not possible in purely planar space. The authors suggest that 1D and 2D patterns of these Lander-DAT molecules could eventually act as molds for nucleating and growing complex metallic nanostructures.



## For Engineering Band Gap, Two Layers of Graphene are Better than One

Graphene, a single-layer-thick sheet of carbon, has been shown to display a variety of unusual electronic and physical properties, including the quantum Hall effect and extremely high electron mobility at room temperature. These unique

characteristics make graphene a candidate for use in many different potential applications, including transistors, integrated circuits, and biosensors. To realize these technologies, researchers will need to understand and to control this material's extraordinary properties. For example, learning how to engineer and to tune band gaps could help realize graphene-based nanoelectronic devices, such as field-effect transistors based on graphene nanoribbons have been demonstrated, mass production is currently impractical. One alternative for creating a band gap is through hydrogenated or bilayer graphene.

Combining these ideas, Samarakoon and Wang (p 4126) explored the electronic and struc-

tural characteristics of hydrogenated bilayer graphene under an electrical bias. Using first-principles density functional calculations, the team found that applying an electrical bias perpendicularly between the graphene layers opens a band gap that can be tuned continuously. As the bias is increased, the band gap collapses, leading to a transition from a semiconductor to a metallic state. Further calculations show that desorption of hydrogen from one layer of the bilayer graphene leads to unpaired spins, which results in a ferromagnetic semiconductor with a tunable band gap. The authors suggest that these findings increase the possibilities for graphene to create more flexible nanodevices that rely on a tunable band gap, such as lasers that change color or electronic circuits that have the ability to rearrange themselves.

