

in the symmetry-breaking property of a membrane filter upon which the nanospheres reside and represents a significant step forward in the fabrication of complex nanocrystal architecture. The membrane serves as a filter for the larger nanospheres capturing them at the surface while allowing the smaller nanoparticles to pass through. As the nanoparticles flow past the nanospheres, they stick to amine groups that coat the nanospheres. The nanoparticles do not adhere to the underneath of the nanospheres during filtration. The researchers stress the importance of controlling the number of nanospheres retained at the surface of the membrane filter to ensure a sufficient number of unblocked pores so that filtration occurs efficiently.

The material allows for the construction of new types of nanoscale architecture; for example, gold nanoparticles on one face of a nanosphere serve as selective binding sites for more gold nanoparticles. The repeated chemisorption of gold nanoparticles results in the templated assembly of multilayers of gold nanoparticles on one half of individual nanospheres.

This research represents an attempt directed toward building complex nanoparticle architecture and the researchers are quick to point out that, for this to be useful, functionality will be necessary. In this regard, their future efforts will demonstrate the utility of similar materials as biochemical tags, templates for the synthesis of new nanostructures, and potential display elements.

YUE HU

Compressive Stress Drives Formation of Bismuth Nanowires

The properties of bismuth have attracted significant interest because of its highly anisotropic Fermi surface, low carrier densities, small carrier effective mass, and long carrier mean free path. Bi nanowires have previously been produced with radii ranging from 7 nm to 200 nm and lengths of up to tens of microns. As reported in the October 21 issue of *Applied Physics Letters*, a group of researchers from General Motors Research and Development Center in Michigan have synthesized Bi nanowires with radii of 30–200 nm and extremely high lengths of several millimeters. Yang-Tse Cheng and co-workers used magnetron sputtering to synthesize a layered structure consisting of chromium nitride and bismuth, which decomposed onto a CrN matrix and Bi nanowires.

The researchers performed the synthe-

sis on a single-crystal Si(111) substrate. The substrates were cleaned and then Ar-ion etched. A 100–200-nm-thick adhesion layer of Cr was then deposited, followed by a thin layer consisting of a mixture of Cr and Bi deposited in an atmosphere of Ar and N₂. The total thickness of the latter films ranged from 1.5 μm to 2.5 μm. The researchers varied the Bi concentration from 1.5 at.% to 4.3 at.% by changing the power on the Bi target while maintaining constant power on the Cr target. Analysis by scanning electron microscopy (SEM) confirmed that the Bi nanowires were formed by compressive stress. Furthermore, SEM revealed a very high growth

rate of ~5 μm/s. By using wafer curvature measurements and Stoney's equation, the researchers measured the compressive stress of ~470 MPa in a Bi-CrN thin film deposited on a silicon substrate.

The research team concluded that the high compressive stress that accompanies the formation of thin films can be used for the formation of metallic nanowires. They reported, "When the high compressive stress is present in a composite thin film consisting of a low melting point material [like Bi, with a melting point of 271°C] and a high melting point matrix material [such as CrN], the low melting point material may be extruded from the

Cost-Effective Portable Spin Coater



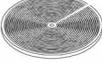
Two-Stage Spinning
 Dispense liquid during Stage 1
 Spin-up and flatten during Stage 2

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Stage 2
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surface to form nanowires at a very high growth rate."

MAXIM P. NIKIFOROV

Low-Temperature Diffusion of Water Clusters on Pd Surfaces Depend Critically on Cluster Size

Working with a scanning tunneling microscope (STM) that can be operated at extremely low temperatures, a research team at the Lawrence Berkeley National Laboratory, led by Miquel Salmeron, a physicist with the Materials Sciences Division, observed the movement of clusters of water molecules on a metal surface. The researchers reported in the September 13 issue of *Science* that the clusters moved across the surface more rapidly than did single molecules, which runs contrary to their previous understanding.

The research team cooled a single crystal of palladium, a good catalyst for reactions involving hydrogen and water, to a temperature of ~40 K in an ultrahigh vacuum. Water molecules were then introduced onto its (111) surface and their motion was tracked with the STM. As expected from previous studies, single molecules migrated across the surface to aggregate into clusters of two (dimers), three (trimers), four (tetramers), five (pentamers), and six (hexamers).

"Isolated water molecules moved by hopping from one lattice point [on the substrate crystal] to the nearest neighboring point whereupon if they collided with another water molecule they began to form clusters," said Salmeron. "The speed with which the molecules moved increased by four orders of magnitude when dimers were formed. The mobility of trimers and tetramers was also very high compared to the isolated molecules."

Salmeron and his colleagues observed that the hydrogen bonds which held two, three, or four water molecules together in a cluster forced the cluster into a geometric configuration that was mismatched with the lattice of the palladium surface. The individual water molecules within these clusters could no longer be bound to the palladium's lattice points with the same strength as when they were isolated. This allowed dimers, trimers, and tetramers to easily slide across the palladium's surface.

When clusters reached five water molecules in size, however, the combined strength of the water-substrate bonds prevailed and the movement of the pentamers slowed or stopped altogether. The addition of a sixth water molecule created highly stable hexamer rings, which spread out as a hexagonal honeycomb structure over the palladium substrate.

Salmeron said, "The hexagonal honeycomb of water molecules does not exactly match palladium's lattice and as a result honeycombs grow to a certain size and then stop, forming islands across the substrate's surface. As additional water molecules are introduced, they pile up on top of these islands. Slight heating will break these islands up into holes that form beautiful patterns, like nanoscale snowflakes."

The interaction of water with surfaces drives a wide variety of important phenomena that include wetting, corrosion, ice-melting, electrochemistry, dissolution, and solvation. Such interactions are equally important to many biological processes.

Salmeron said, "Numerous fundamental questions regarding the adsorption of water on surfaces and its evolution from isolated molecules to clusters, complete

Metallic Hydrogen Decoration Results from Hydrogen Adsorption on SWNT

Many carbon materials have excellent molecular adsorption and sieving properties. Because of their many unusual mechanical and electronic properties, single-walled carbon nanotubes (SWNTs) have been studied extensively for their potential in the fabrication of nanodevices and components in molecular-scale machines and electronics. Since structural deformation of SWNTs can give rise to significant physicochemical properties, researchers O. Gülseren at the University of Pennsylvania, T. Yildirim at the NIST Center for Neutron Research in Maryland, and S. Ciraci at Bilkent University in Turkey investigated structural and electronic properties of hydrogenated SWNTs (H-SWNTs) as a function of hydrogen coverage and decoration by extensive first-principles calculations. The team showed how changing the shape of tiny single-walled tubes of carbon may open a potential mother lode of technologically useful properties.

The new calculations by Yildirim and his colleagues, published in the September 15 issue of *Physical Review B*, indicated that strategically placing hydrogen on the exterior of carbon nanotubes leads to dramatic changes in their electronic and atomic structures. One of the most important results in this study was that upon hydrogenation at uniform half coverage, the zigzag $(n,0)$ SWNTs are metallized with high density of states at the Fermi level. Surprisingly, the cross section of the nanotube—initially cylindrical—becomes rectangular, with a diamondlike carbon atom at each corner, as shown in the figure. These chemically passive carbon atoms isolate the four conducting faces of the H-SWNT, yielding a "four-wire nanocable," said Yildirim. Because of the high density of conduction electrons in this particular configuration, he said, it may be possible to chemically engineer nanotube wires that are ideal one-dimensional conductors or are even superconducting.

For other isomers at half coverage as well as exo- and endo-exohydrogenations at full coverage, the cross sections remain quasi-circular and electronic structures vary greatly among the resultant materials. For example, the chain pattern H-SWNTs exhibit a small bandgap of ~2 eV while the dimer pattern H-SWNTs exhibit a bandgap of ~4 eV. The team's calculations show that selective bonding of hydrogen to nanotubes can give rise to a number of potentially useful applications in the emerging field of molecular electronics.

KINSON C. KAM

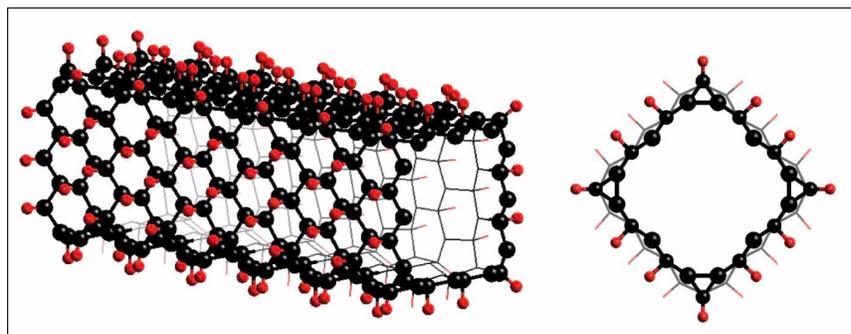


Figure. A side and top view of a hydrogenated $(8,0)$ single-walled carbon nanotube at half coverage. Red and black represent H and C atoms, respectively.