group also compared the properties of untreated composite fibers containing MWNTs to those containing single-walled nanotubes (SWNTs).

The scientists spun their continuous fibers by injecting a homogeneous dispersion of nanotubes into a co-flowing stream of aqueous PVA. They then investigated the mechanical properties under tensile load. Toughness is measured by the specific amount of energy that is required to break a fiber and the amount of strain tolerated before failure. Their untreated SWNT fibers reached a record strain-to-failure of 430% and an unprecedented toughness of 870 J/g. Untreated MWNT/PVA fibers performed nearly as well. These composite fibers are an order of magnitude tougher than polyaramide fibers such as Kevlar.

Unfortunately, classical nanotube/PVA composite fibers swell and lose strength in humid conditions, and they absorb relatively little energy at low strain, compared with polyaramides. Miaudet and co-workers drew inspiration from textile technologies and remedied both drawbacks by hot-drawing their nanotube/ PVA fibers. After drying the fibers, they pulled them to 850% within a hot air stream at 180ºC, which is above the PVA glass transition.

X-ray diffraction confirms that the hot-drawing process increases the crystallinity of the PVA and further aligns the PVA chains and the nanotubes. This microstructural change enhances the stress transfer between the polymer and the nanotubes. The hot-drawn fibers are radically stronger and absorb much more energy at lower strain. Furthermore, because crystalline PVA does not dissolve in water at room temperature, the treated fibers retain their mechanical properties in humid conditions and do not become bloated, even when submerged.

Even stronger fibers are a possibility. "The nanotubes are still not as well-aligned as the PVA chains are," said Miaudet, "but this problem may be solved if we use straighter or less entangled nanotubes. It is predicted that the Young's modulus will grow by an order of magnitude during the last degrees of alignment."

RICH LOUIE

Single Screw-Sense Cylindrical Nanoshutter Driven by Thermal and Solvent-Polarity Changes

Molecular motors are nanomachines that perform work by transforming low-input energy sources, such as thermal energy or solvent-polarity changes, into mechanical motion. Potential applications for nanomotors include data storage, optical devices, and liquid-crystalline displays. Recently, researchers from the Department of Chemistry at North Carolina State University (Raleigh, N.C.), and the Department of Chemistry at Vanderbilt University (Nashville, Tenn.) developed a new model for a nanomotor—a cylindrical shutter consisting of a thermal and solvocontrollable switching polyguanidine derivative—in which the switching phenomena does not involve inversion of the polymer backbone.

As reported in the November 11, 2005, issue of *Angewandte Chemie International Edition* (p. 7298; DOI: 10.1002/anie.200501977), North Carolina State University researcher B.M. Novak, Vanderbilt University researcher P.L. Polavarapu, and co-researchers used helix-sense-selective polymerization to synthesize the species shown in Figure 1, which is chiral because the backbone possesses a single-handed screw sense and the anthracene and imine are stereoregular. While complete racemization requires high temperatures and long periods of time (nearly 80°C and >100 h), switching of electronic circular dichroism (ECD) and UV–vis spectra occurs within seconds at moderate temperatures. At 38.5°C, the Cotton effect (i.e., the production of circular birefringence under electromagnetic radiation) at 382 nm in ECD spectra switches from positive to negative. Similarly, UV–vis spectra show a strong absorption at 382 nm at 25°C, but a weaker absorption at 60°C. Concomitant switching of the vibra-

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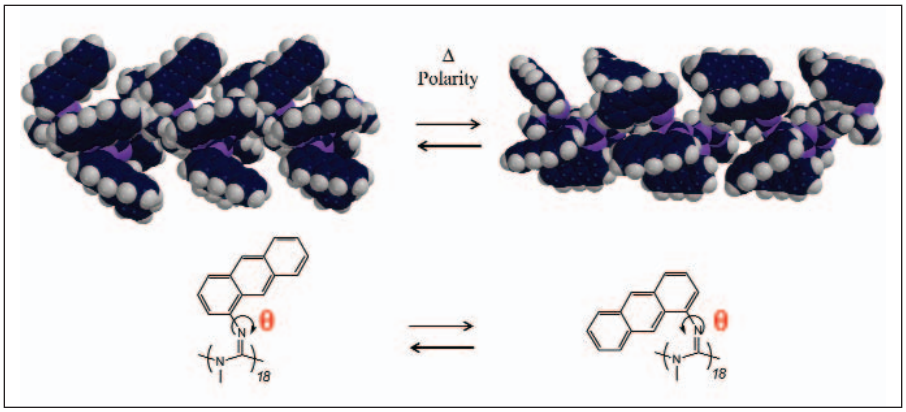

Figure 1. Theoretical models of the two states that result from the shutter-like motions of the anthracene unit.

tional circular dichroism (VCD), however, was not observed, which the researchers said indicated that the helical pitch remained constant during the other switching processes. The researchers reasoned that these observations can only be reconciled if the anthracene units wag synchronously around the N–C bonds in the anthracene moieties, which would change the orientation of the anthracenes relative to the nitrogens' lone-pair electrons (see Figure 1).

The researchers confirmed their hypothesis with theoretical molecular models. Using a molecular model similar to the repeat unit in Figure 1 (suitably capped with hydrogens), semiempirical molecular orbital theory was used to show that shutter-like motions of the anthracenes do not affect the helical pitch or the imine configuration. The researchers obtained the same result for an 18-mer using molecular mechanics simulations. The researchers also performed density functional theory (DFT) calculations to obtain a theoretical VCD spectrum, which is in excellent agreement with the experimental spectrum, and to assign the chirality, which is difficult to do experimentally, as *P*. The researchers said that, "Further modification and applications are currently under investigation."

STEVEN TROHALAKI

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