Telescoping nanotubes offer new option for nonvolatile memory

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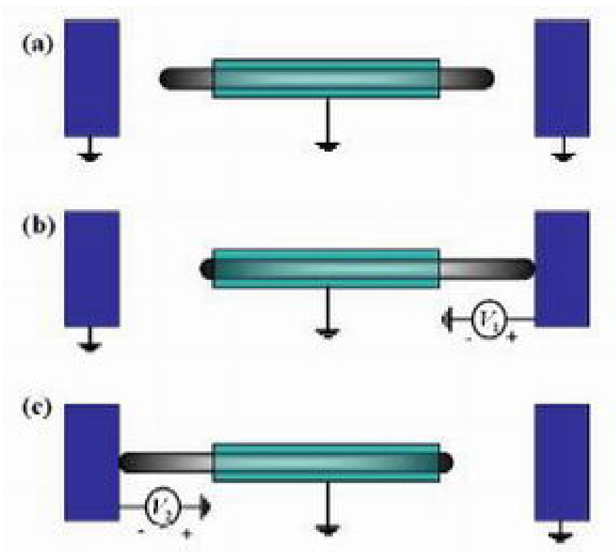

Design of the telescoping carbon nanotube in three positions: (a) equilibrium, (b) inner nanotube in contact with right electrode, and (c) inner nanotube in contact with left electrode. An applied electrostatic force pulls the inner nanotube to the desired position. Credit: Jeong Won Kang, et al.

In the midst of a widespread and potentially highly lucrative search for next-generation nonvolatile memory, scientists from the University of California have put to use an interesting characteristic of carbon nanotubes. When one hollow nanotube is inserted into a second (slightly larger) nanotube, scientists can achieve a rapid telescoping motion that can be applied to binary or triple digit memory for future molecular-scale computers.

Although nonvolatile memories are common today—from cell phone cards to CDs to hard drives and flash disks—scientists envision a nonvolatile memory whose high speed and power would take the place of Random Access Memory (RAM). RAM's high-speed currently makes it responsible for displaying applications and data while the computer is on, but it is a volatile memory, meaning all data is lost when the power is turned off.

A next-generation nonvolatile memory would combine the speed of RAM and nonvolatility—enabling computers to boot up as fast as you can turn on the TV, as well as eliminating the need for secondary storage devices (such as external hard drives).

"Research and development on molecular-scale memory and electronics, including data storage and computing devices, are extremely vibrant in the worldwide research communities," scientist Qing Jiang told *PhysOrg.com*. "One of the widely perceived advantages is revolutionary advancements in density and speed, compared to the current silicon technology."

During the past few years, scientists have investigated the telescoping motion of nanotubes for nano applications, opening up the possibility for data storage. Now, Jiang and Jeong Won Kang have designed a device that could provide both nonvolatile RAM and terabit solid-state storage based on these telescoping nanotubes. The scientists also analyzed their design's dynamic characteristics using molecular dynamics simulations to narrow down the best possible design.

In the set-up, the movable core nanotube can slide inside a stationary nanotube by varying the electrostatic forces. This "telescope" lies between two electrodes, which are neutral when at rest. But by negatively charging one of the electrodes and positively charging the core nanotube, the nanotube can overcome the van der Waals force keeping the inner and outer nanotubes together, and move toward the oppositely charged electrode. Alternatively, by positively charging the other electrode and negatively charging the core nanotube, the nanotube would slide the other way. High damping would send the core nanotube back in the center.

The contact between the core nanotube and an electrode creates a conduction pathway, and can be determined by measuring the resistance in this area, which marks a junction. With three possible positions (right electrode contact, left electrode contact, and no contact), the device could occupy three states, and therefore write one of three bits.

As Kang and Jiang emphasize, getting the core nanotube to stay in contact with an electrode, even after removal of the electrical field, is vital for performance. This “bistability” requires balancing all the forces that act upon the sliding core nanotube, in an effort to obtain the correct collision time at a high speed. With platinum electrodes, the scientists’ simulation achieved switching times of around 10^{-11} seconds, and data erasing times of around 10^{-12} seconds—very competitive with top designs.

“The demonstrated bi-stability, stable at two different telescoped positions, of this nanotube unit makes it feasible for the unit to behave as a switch, i.e., switching from one stable position to the other, and thus to serve as a non-volatile memory,” Jiang explained.

Kang and Jiang’s research shows optimism for telescoping nanotubes, although the application is still in its early stages. For example, the scientists performed their simulations at the very low temperature of 1K, meaning further research must investigate the dynamics at room temperature.

Overall, predictions vary widely in the field of next-generation nonvolatile memory technologies, especially regarding how long it will take for a fully mature and commercially viable type to accommodate a wide range of devices, and—in a more competitive spirit—exactly which technology(ies) that will be.

“The prospects for the perceived revolutionary advancements have led to active research and development programs in many major corporations, such as Hewlett-Packard, IBM, Lucent, Motorola, Siemens, and Hitachi, etc.,” said Jiang. “It is likely that a functioning prototype of a molecular processor will be demonstrated in the next two to three years, but commercialization will face many challenges, such as the lack of infrastructure for mass production.”

For more information on telescoping nanotubes, see Jiang’s Webpage: www.engr.ucr.edu/~qjiang/ .

Citation: Kang, Jeong Won, and Jiang, Qing. “Electrostatically telescoping nanotube nonvolatile memory device.” *Nanotechnology* 18 (2007) 095705 (8pp).