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Researchers develop bistable nano switch

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Carbon nanotubes (CNT) have been under intense study by scientists all over the world for more than a decade and are being thought of as ideal building blocks for nanoelectromechanical systems (NEMS). A type of one-dimensional structure with high-aspect ratio, carbon nanotubes have emerged as a promising material because of their many impressive mechanical, electrical and chemical properties.

Now scientists from Northwestern University have demonstrated a novel carbon nanotube-based nanoelectromechanical switch exhibiting bistability based on current tunneling. The device could help advance technological developments in memory chips and electronic sensing devices.

The research is published online by the scientific journal *Small*.

"We believe the unique characteristics of this nano device will likely lead to many high-impact applications in the field of nanoelectronics and nanosensors," said Horacio Espinosa, professor of mechanical engineering in the McCormick School of Engineering and Applied Science. Espinosa and Changhong Ke, a former graduate student of Espinosa's, co-authored the paper.

Since the invention of the integrated circuit (IC), the semiconductor industry has boomed following the famous Moore's law. However, as the characteristic dimension achievable by various photolithography techniques approaches its physical limits, scientists are searching for new materials and new device concepts to be able to continue the large-scale integration trend.

"Although several carbon nanotube-based NEMS devices have been proposed, frankly, none of them has reached the level of commercial success," said Espinosa. "There are many challenges associated with nanofabrication and reliability."

Nanoscale manufacturing is complex and too expensive, imposing significant challenges to the design of nano devices. Assessing device reliability based on nanoscale experimentation is one big challenge. For example, placement of nano-objects at desired locations is difficult and lacks reproducibility. Likewise, real-time observation and characterization of mechanical motion requires the use of in-situ electron microscopy and electronic measurement techniques capable of controlling noise and parasitic effects.

Espinosa and his team solved some of these issues by designing and demonstrating a tunneling bistable switch. The device is made of a free suspended multiwalled carbon nanotube interacting electrostatically with an underlying electrode. In the device circuit, there is a resistor in series with the nanotube, which plays an important role in the functioning of the device by adjusting the voltage drop between the nanotube and the underlying electrode.

"The design of the device looks very simple, but the theories behind it are very complex and span several disciplines, including quantum mechanics, electronics and mechanics," said co-inventor Ke, now a post-doctoral fellow at Duke University. "Also, a major advantage of our device is its geometry, which is fully compatible with current manufacturing techniques for mass production."

Espinosa and Ke demonstrated the behaviors of the device by mounting individual carbon nanotubes to the tip of a tungsten probe using a nanomanipualtor inside a scanning electron microscope. Then the nanotube was actuated by applying a potential to an adjustable micron-size gap between the nanotube and an electrode. The motion of the nanotube was recorded by the electron microscope, and the current in the circuit was recorded by a source-measurement unit.

Northwestern has filed a patent application covering the concept of the bistable tunneling device and its application and is seeking commercial partners to develop the technology. The potential applications of the device include NEMS switches, random-access memory elements and logic devices.

Source: Northwestern University