Carbon nanotube finding could lead to flexible electronics with longer battery life

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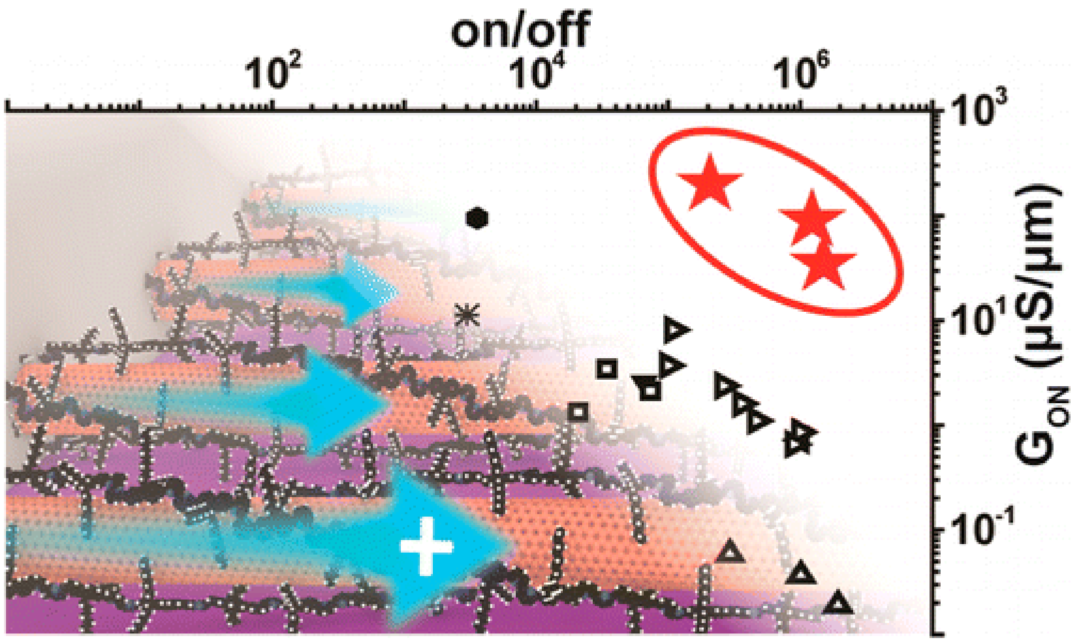

University of Wisconsin-Madison materials engineers have made a significant leap toward creating higher-performance electronics with improved battery life—and the ability to flex and stretch.

Led by materials science Associate Professor Michael Arnold and Professor Padma Gopalan, the team has reported the highest-performing carbon nanotube transistors ever demonstrated. In addition to paving the way for improved consumer electronics, this technology could also have specific uses in industrial and military applications.

In a paper published recently in the journal *ACS Nano*, Arnold, Gopalan and their students reported transistors with an on-off ratio that's 1,000 times better and a conductance that's 100 times better than previous state-of-the-art carbon nanotube transistors.

"Carbon nanotubes are very strong and very flexible, so they could also be used to make flexible displays and electronics that can stretch and bend, allowing you to integrate electronics into new places like clothing," says Arnold. "The advance enables new types of electronics that aren't possible with the more brittle materials manufacturers are currently using."

Carbon nanotubes are single atomic sheets of carbon rolled up into a tube. As some of the best electrical conductors ever discovered, carbon nanotubes have long been recognized as a promising material for next-generation transistors, which are semiconductor devices that can act like an on-off switch for current or amplify current. This forms the foundation of an electronic device.

However, researchers have struggled to isolate purely semiconducting carbon nanotubes, which are crucial, because metallic nanotube impurities act like copper wires and "short" the device. Researchers have also struggled to control the placement and alignment of nanotubes. Until now, these two challenges have limited the development of high-performance carbon nanotube transistors.

Building on more than two decades of carbon nanotube research in the field, the UW-Madison team drew on cutting-edge technologies that use polymers to selectively sort out the semiconducting nanotubes, achieving a solution of ultra-high-purity semiconducting carbon nanotubes.

Previous techniques to align the nanotubes resulted in less-than-desirable packing density, or how close the nanotubes are to one another when they are assembled in a film. However, the UW-Madison researchers pioneered a new technique, called floating evaporative self-assembly, or FESA, which they described earlier in 2014 in the ACS journal *Langmuir*. In that technique, researchers exploited a self-assembly phenomenon triggered by rapidly evaporating a carbon nanotube solution.

The team's most recent advance also brings the field closer to realizing carbon nanotube transistors as a feasible replacement for silicon transistors in computer chips and in high-frequency communication devices, which are rapidly approaching their physical scaling and performance limits.

"This is not an incremental improvement in performance," Arnold says. "With these results, we've really made a leap in carbon nanotube transistors. Our carbon nanotube transistors are an order of magnitude better in conductance than the best thin film transistor technologies currently being used commercially while still switching on and off like a transistor is supposed to function."

The researchers have patented their technology through the Wisconsin Alumni Research Foundation and have begun working with companies to accelerate the technology transfer to industry.

More information: *ACS Nano*, pubs.acs.org/doi/abs/10.1021/nn5048734

Langmuir, pubs.acs.org/doi/abs/10.1021/la500162x

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