Study highlights the potential of nanotube digital electronics

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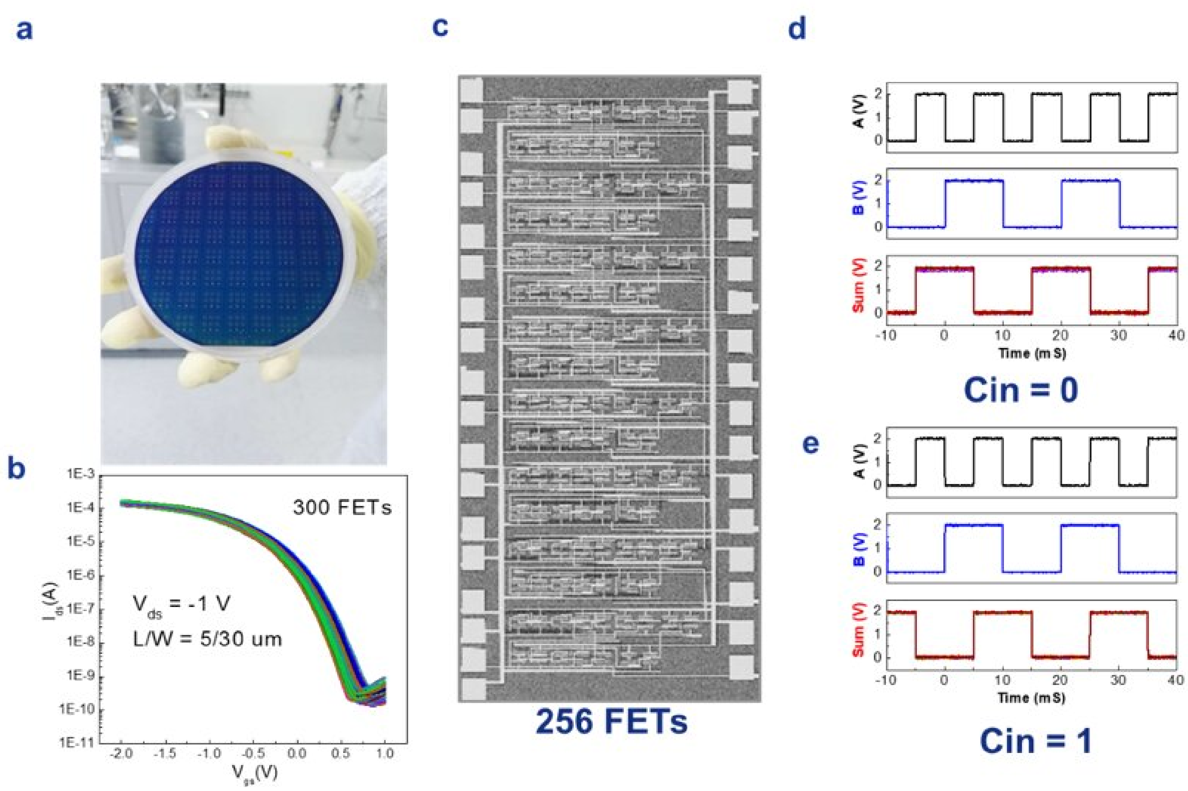

Device uniformity and medium-scale CNT integrated circuits. (a) Optical image showing a wafer covered with CNT FETs, with (b) corresponding transfer characteristics of 300 FETs. (c) SEM image showing a CNT 8-bit full adder CMOS circuit composed of 256 CNT FETs, with input (A and B) and output (Sum) waveform of the sum for a carry-in (d) Cin=0 and (e) Cin=1 from a previous addition. Credit: Dr. Haitao Xu.

Some experts in the field of electronics engineering have suggested that the use of silicon complementary metal-oxide semiconductors (CMOS) will start declining rapidly by the end of 2020. Despite their predictions, a class of alternative materials that can effectively sustain the computational power of new devices, while maintaining good energy efficiencies is yet to be clearly established.

Over the past few years, researchers have proposed several materials that could ultimately substitute current CMOS devices. Some of the most promising candidates are carbon nanotube (CNT)-based electronics, which can be fabricated using a variety of different techniques.

A team of researchers at Peking University and Xiangtan University in China has recently carried out a study investigating the potential of CNT materials for fabricating electronics. In their paper, published in *Nature Electronics*, the researchers discussed the development of nanotube-based CMOS field-effect transistors over time, while also highlighting some of the CNT materials that are currently available to electronics manufacturers.

"CNT is an ideal electronic material that offers solutions where other semiconductors fundamentally fail, particularly when scaled to the sub-10 nm dimensional scale," Lianmao Peng, one of the researchers who carried out the study, told TechXplore. "In this work, we demonstrated that CNT based electronics have the potential to outperform that of silicon technology by a large margin (experimentally demonstrated over ten times advantage) and that large-scale integrated circuits (ICs) can be constructed using carbon nanotubes."

The relevant physical parameters of CNTs, such as their structure and electronic properties, are now well-known in the field. To effectively explore the potential limitations of CNT materials, Peng and his colleagues Zhiyong Zhang and Chenguang Qiu thus analyzed the performance and qualities of individual CNTs, focusing on these specific parameters.

"Our results show that at sub-10 nm technology nodes, CNT transistors can be 3 times faster, and 4 times more energy efficient than their silicon counterparts," Peng explained. "We demonstrated that, even using the very limited university fabrication facility, we can fabricate transistors that outperform silicon transistors by many times, indicating that the chip industry could move ahead with the current speed for many more decades."

The study carried out by Peng and his colleagues provides further evidence suggesting that CNT transistors are a viable and desirable alternative to current silicon CMOS devices. In their analyses, the researchers also highlighted some of the advantages and disadvantages of the medium-scale integrated circuits that have been developed to date, as well as the challenges that are currently preventing their large-scale implementation.

According to Peng and his colleagues, developing integrated circuits (ICs) with new 3-D chip structures could enhance the performance of CNT materials further, making them up to hundreds of times more powerful. Their analyses and previous findings gathered by other research teams ultimately hint at the possibility of CNT technology being the solution to deliver more powerful and highly energy efficient chip technology in the post-Moore era.

"Right now, we can fabricate few extremely powerful transistors on individual CNTs, but not very complicated ICs," Peng said. "On the other hand, we can build CNT based ICs with over 10k transistors in three-dimensions using CNT thin film but with very limited performance. In the future, we need to combine the two directions of research, building high-performance large-scale ICs using CNT films with performance exceeding that of silicon chip technology."

More information: Lian-Mao Peng et al. Carbon nanotube digital electronics, *Nature Electronics* (2019). DOI: 10.1038/s41928-019-0330-2