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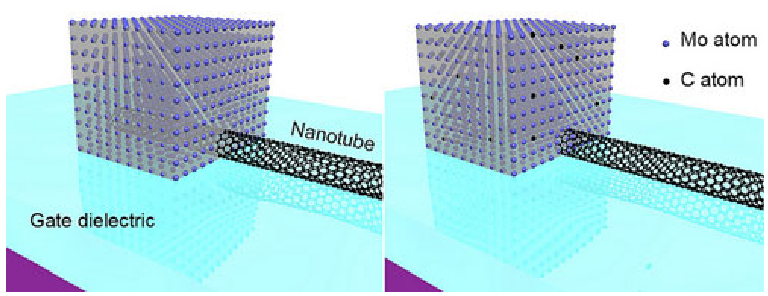
Posted: Oct 01, 2015

# Research breakthrough paves way for post-silicon future with carbon nanotube electronics

(*Nanowerk News*) IBM Research today announced a major engineering breakthrough that could accelerate carbon nanotubes replacing silicon transistors to power future computing technologies.

IBM scientists demonstrated a new way to shrink transistor contacts without reducing performance of carbon nanotube devices, opening a pathway to dramatically faster, smaller and more powerful computer chips beyond the capabilities of traditional semiconductors. The results will be reported in the October 2 issue of *Science* ("End-bonded contacts for carbon nanotube transistors with low, size-independent resistance").



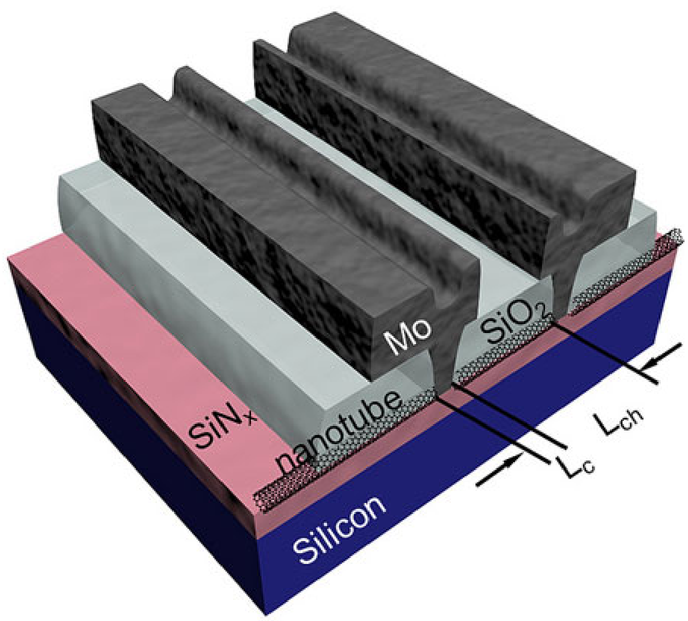

*Schematics showing the conversion from a side-bonded contact (left), where the SWNT is partially covered by Mo, to end-bonded contact (right), where the SWNT is attached to the bulk Mo electrode through carbide bonds while the carbon atoms from originally covered portion of the SWNT uniformly diffuse out into the Mo electrode.*

Carbon nanotube chips could greatly improve the capabilities of high performance computers, enabling Big Data to be analyzed faster, increasing the power and battery life of mobile devices and the Internet of Things, and allowing cloud data centers to deliver services more efficiently and economically.

Silicon transistors, tiny switches that carry information on a chip, have been made smaller year after year, but they are approaching a point of physical limitation. With Moore's Law running out of steam, shrinking the size of the transistor – including the channels and contacts – without compromising performance has been a vexing challenge that have troubled researchers for decades.

IBM has previously shown that carbon nanotube transistors can operate as excellent switches at channel dimensions of less than ten nanometers – the equivalent to 10,000 times thinner than a strand of human hair and less than half the size of today's leading silicon technology. IBM's breakthrough in creating a new contact approach overcomes the other major hurdle in incorporating carbon nanotubes into semiconductor devices, which could result in smaller chips with greater performance and lower power consumption.

Earlier this summer, IBM unveiled the first 7 nanometer node silicon test chip, pushing the limits of silicon technologies and ensuring further innovations for IBM Systems and the IT industry. By advancing research of carbon nanotubes to replace traditional silicon, IBM is paving the way for a post-silicon future and delivering on its $3 billion chip R&D investment announced in July 2014.




*Schematic of a set of Mo end-contacted nanotube transistors made on the same nanotube with $L_c$ ranging from ~10 to 60 nm defined by $SiO_2$ contact trenches.*

"These chip innovations are necessary to meet the emerging demands of cloud computing, Internet of Things and Big Data systems," said Dario Gil, vice president of Science & Technology at IBM Research. "As technology nears the physical limits of silicon, new materials and circuit architectures must be ready to deliver the advanced technologies that will drive the Cognitive Computing era. This breakthrough shows that computer chips made of carbon nanotubes will be able to power systems of the future sooner than the industry expected."

**A New Contact for Carbon Nanotubes**

Carbon nanotubes represent a new class of semiconductor materials that consist of single atomic sheets of carbon rolled up into a tube. The carbon nanotubes form the core of a transistor device whose superior electrical properties promise several generations of technology scaling beyond the physical limits of silicon.

Electrons in carbon transistors can move more easily than in silicon-based devices, and the ultra-thin body of carbon nanotubes provide additional advantages at the atomic scale. Inside a chip, contacts are the valves that control the flow of electrons from metal into the channels of a semiconductor. As transistors shrink in size, electrical resistance increases within the contacts, which impedes performance. Until now, decreasing the size of the contacts on a device caused a commensurate drop in performance – a challenge facing both silicon and carbon nanotube transistor technologies.

IBM researchers had to forego traditional contact schemes and invented a metallurgical process akin to microscopic welding that chemically binds the metal atoms to the carbon atoms at the ends of nanotubes. This 'end-bonded contact scheme' allows the contacts to be shrunken down to below 10 nanometers without deteriorating performance of the carbon nanotube devices.

"For any advanced transistor technology, the increase in contact resistance due to the decrease in the size of transistors becomes a major performance bottleneck," said Shu-Jen Han, manager of the Nanoscale Science & Technology Group at IBM Research. "Our novel approach is to make the contact from the end of the carbon nanotube, which we show does not degrade device performance. This brings us a step closer to the goal of a carbon nanotube technology within the decade."

Source: *IBM*



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