Carbon nanotubes outperform copper nanowires as interconnects

March 13 2008

Researchers at Rensselaer Polytechnic Institute have created a road map that brings academia and the semiconductor industry one step closer to realizing carbon nanotube interconnects, and alleviating the current bottleneck of information flow that is limiting the potential of computer chips in everything from personal computers to portable music players.

To better understand and more precisely measure the key characteristics of both copper nanowires and carbon nanotube bundles, the researchers used advanced quantum-mechanical computer modeling to run vast simulations on a high-powered supercomputer. It is the first such study to examine copper nanowire using quantum mechanics rather than empirical laws.

After crunching numbers for months with the help of Rensselaer's Computational Center for Nanotechnology Innovations, the most powerful university-based supercomputer in the world, the research team concluded that the carbon nanotube bundles boasted a much smaller electrical resistance than the copper nanowires. This lower resistance suggests carbon nanotube bundles would therefore be better suited for interconnect applications.

"With this study, we have provided a road map for accurately comparing the performance of copper wire and carbon nanotube wire," said Saroj Nayak, an associate professor in Rensselaer's Department of Department of Physics, Applied Physics, and Astronomy, who led the research team. "Given the data we collected, we believe that carbon nanotubes at 45 nanometers will outperform copper nanowire."

The research results will be featured in the March issue of *Journal of Physics: Condensed Matter*.

Because of the nanoscale size of interconnects, they are subject to quantum phenomena that are not apparent and not visible at the macroscale, Nayak said. Empirical and semi-classical laws cannot account for such phenomena that take place on the atomic and subatomic level, and, as a result, models and simulations based on those models cannot be used to accurately predict the behavior and performance of copper nanowire. Using quantum mechanics, which deals with physics at the atomic level, is more difficult but allows for a fuller, more accurate model.

"If you go to the nanoscale, objects do not behave as they do at the macroscale," Nayak said. "Looking forward to the future of computers, it is essential that we solve problems with quantum mechanics to obtain the most complete, reliable data possible."

The size of computer chips has shrunk dramatically over the past decade, but has recently hit a bottleneck, Nayak said. Interconnects, the tiny copper wires that transport electricity and information around the chip and to other chips, have also shrunk. As interconnects get smaller, the copper's resistance increases and its ability to conduct electricity degrades. This means fewer electrons are able to pass through the copper successfully, and any lingering electrons are expressed as heat. This heat can have negative effects on both a computer chip's speed and performance.

Researchers in both industry and academia are looking for alternative materials to replace copper as interconnects. Carbon nanotube bundles are a popular possible successor to copper, Nayak said, because of the material’s excellent conductivity and mechanical integrity. It is generally accepted that a quality replacement for copper must be discovered and perfected in the next five to 10 years in order to further perpetuate Moore’s Law – an industry mantra that states the number of transistors on a computer chip, and thus the chip’s speed, should double every 18-24 months.

Nayak said there are still many challenges to overcome before mass-produced carbon nanotube interconnects can be realized. There are still issues concerning the cost of efficiency of creating bulk carbon nanotubes, and growing nanotubes that are solely metallic rather than their current state being of partially metallic and partially semiconductor. More study will also be required, he said, to model and simulate the effects of imperfections in carbon nanotubes on the electrical resistance, contact resistance, capacitance, and other vital characteristics of a nanotube interconnect.

Source: Rensselaer Polytechnic Institute

Citation: Carbon nanotubes outperform copper nanowires as interconnects (2008, March 13) retrieved 19 April 2024 from
https://phys.org/news/2008-03-carbon-nanotubes-outperform-copper-nanowires.html