Purdue researchers look at nanotechnology to reduce computer-chip heating

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By John McHale

WEST LAFAYETTE, Ind. - In the military and the commercial world, electronic system designers want more and more processing performance out of computer chips, yet heat from these super chips creates a lot of headaches for the engineers tasked with keeping computer boards cool.

Researchers at Purdue University in West Lafayette, Ind., are looking to mitigate the heating problem through the use of carbon nanotubes, which resemble tiny cylinders. They have created carpets of microscopic nanotubes to enhance the performance of heat sinks to help keep future chips from overheating.

Researchers are trying to develop new types of thermal interface materials that move heat more efficiently than conventional materials to meet cooling needs of future chips. The materials, which are sandwiched between silicon chips and the metal heat sinks, fill gaps, and irregularities between the chip and metal surfaces to enhance heat flow between the two.

Purdue researchers have made several new thermal interface materials with carbon nanotubes, including a Velcro-like nanocarpet. The nanotube carpets also might have military and other commercial applications for cooling power electronics that control the flow of electrical power on aircraft, ships, and vehicles.

Cooling is such a huge issue that the major chipmakers are hearing their customer's cries and introducing power-efficient chips. Intel just started releasing chips based on its Core Microarchitecture, which claims to improve performance while reducing wattage and heat. AMD is addressing the power and cooling needs with its line of Multi-Core solutions.

"The bottom line is the performance that we see with nanotubes is significantly better than comparable state-of-the-art commercial materials," says Timothy Fisher, an associate professor of mechanical engineering who is leading the research. "Carbon nanotubes have excellent heat-conduction properties, and our ability to fabricate them in a controlled manner has been instrumental in realizing this application."

Funding the research is Purdue's Cooling Technologies Research Center, supported by the National Science Foundation, industry, and Purdue to help corporations develop miniature-cooling technologies for applications from electronics and computers to telecommunications and advanced aircraft.

Applications in power electronics are being supported by the Air Force Research Laboratory in association with the Birck Nanotechnology Center at Purdue's Discovery Park.

Recent findings have shown that nanotube-based interfaces can conduct several times more heat than conventional thermal interface materials at the same temperatures. The nanocarpet, called a "carbon-nanotube-array thermal interface," can be attached to the chip and heat-sink surfaces.

"We say it's like Velcro because it creates an interwoven mesh of fibers when both sides of the interface are coated with nanotubes," Fisher says. "We don't mean that it creates a strong mechanical bond, but the two pieces come together in such a way that they facilitate heat flow, becoming the thermal equivalent of Velcro. In some cases, using a combination of nanotube material and traditional interface materials also shows a strong synergistic effect."

Findings related to the combination of carbon nanotubes and traditional interface materials are detailed in a paper by mechanical-engineering doctoral student Jun Xu and Fisher that appears in the May issue of *International Journal of Heat and Mass Transfer*.

As heat flows through conventional thermal interface materials, the temperature rises about 15 degrees Celsius, whereas the nanotube-array material causes a rise of about 5 degrees or less.

It will be necessary to find more efficient thermal interface materials in the future because as computer chips become increasingly more compact, more circuitry will be patterned onto a smaller area, producing additional heat, which reduces the performance of computer chips and can ultimately destroy the delicate circuits, Fisher says.

The nanotubes range in diameter from less than one nanometer to about 100 nanometers. A nanometer is a billionth of a meter, or about the distance of 10 atoms strung together, Purdue researchers say.

The technology is ready for commercialization and is being pursued by several corporate members of the cooling research center, including Nanoconduction Inc., a start-up company in Sunnyvale, Calif., which is a new member of the cooling center.