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'Nano-lightning' could cool microchips without moving parts
By CHARLES CHOI
United Press International

NEW YORK, March 24, 2004 -- A novel technique to cool microchips harnesses miniature lightning bolts to propel cooling winds over electronics without moving parts such as fans.

The new method could enable the use of higher-performance chips, which otherwise would melt under their own heat, and result in more powerful laptop and desktop computers.

"It will enable the further miniaturization of computers and similar devices," researcher Daniel Schlitz, a mechanical engineer at Purdue University in West Lafayette, Ind., told United Press International. "It will make these products more portable and increase their functionality."

Schlitz and colleagues have filed a patent application for their technique and created a company called Thornn Micro Technologies to commercialize it.

"This is a groundbreaking idea," said Purdue mechanical engineer Suresh Garimella. "It is certainly one of the most inventive things I've ever been involved with."

Garimella directs Purdue's Cooling Technologies Research Center, a consortium of industry leaders, government laboratories and universities, whose members include Cisco, Intel, Apple, Sony, Nokia, Alcoa, General Electric and Honeywell. Cooling is critical to electronics, as evidenced by the thermal management technology market, estimated at $3.2 billion by Business Communications Co., an economic analysis firm in Norwalk, Conn.

As computer manufacturers strive to squeeze greater performance from chips, they must cram the circuits ever more closely together. This process confines heat and places chips at risk of meltdown.

The microchips in current desktop computers are cooled via metal fins that radiate their heat. The fins are coupled to bulky fan assemblies to carry away heated air. Conventional fans take up too much space and energy for laptop computers, so manufacturers use hollow copper heat pipes to conduct heat.

The new technique uses electrodes made of nanotubes of carbon with tips only as wide as 5 nanometers, or billionths of a meter. When activated, electrical charge imbalances between the nanotubes result in tiny lightning bolts that electrify or ionize the air surrounding them.

Although storms require thousands of volts to generate lightning bolts, "we do it with 100 volts or less," Garimella said. "In simple terms, we are generating a kind of lightning on a nano-scale here."

They can use low voltages because the electrodes, or contact points, are only about 10 microns apart -- about one-tenth the width of a human hair. Such close spacing can generate powerful electric fields despite low voltages, fields powerful enough to pull electrons directly out of the electrodes.

The free electrons, or ions, form clouds that can be moved via electrical attraction or repulsion. By switching the voltages of electrodes roughly a million times per second, the ions "make repeated collisions with neutral molecules, producing the breeze," Schlitz said.

He said the device should generate airflow speeds of 2 mph to 20 mph, "comparable to a fan." At the same time, the device could be up to 10 times smaller than a conventional fan and heat transfer system.

"It's fair to say it should be comparable to or less in size than current liquid-cooled systems and a lot less bulky than conventional air-cooled systems," Garimella said. "We've made some estimates, and they should be quite, quite cheap. If made in bulk, they should be a couple of dollars a piece, quite comparable and certainly less expensive than liquid-cooled systems."

Right now, Schlitz explained, the "micro-scale, ion-driven airflow" device, as it is called, is only at the lab research stage. More work must be done to develop a prototype, including experiments to calculate the device's performance.

Schlitz said he thinks the device could be ready for commercial applications in two years. Garimella added that future versions of the device could replace carbon nanotubes with a thin diamond film, which could prove sturdier and easier to fabricate than nanotubes.

The hope is to have cooling devices small enough to fit on circuits, actually making up a layer on a chip.

"This would have no moving parts, making it quiet and reliable," Fisher said.

Inventors at several companies, such as Cooligy, in Mountain View, Calif., a Stanford University spinoff, are working on systems that circulate liquids to draw heat from chips.

"Of course, people don't want liquids around electronics," Garimella told UPI. In general, he said, liquid-cooled systems are also more expensive.

"Using air to cool these systems is desirable if possible, because air is readily available, doesn't need to be stored within the system, and is environmentally benign," said Richard Smith, National Science Foundation program director of thermal transport and thermal processing.

"It is probably essential for portable devices such as laptop computers, cell phones, sensing systems, many types of microelectronics that must be portable," Smith told UPI. "If one could find a way to move the air through micron-sized flow channels without noisy, heavy fans, then cooling of these devices could be more effective."

The key feature of Garimella's team's new work "is that it sticks with air cooling while possibly providing the same rate of cooling as a liquid," Smith explained.

He called micro-scale ion-driven airflow one of a number of technologies that offer a lot of promise.

"I wouldn't say it's the only way that NSF would endorse as a next-generation cooling device," he said, "because there are other avenues of investigation along those lines, but it's fundamentally important work."

Understanding lightning-driven flows could also help advance other technologies, Smith suggested, including that of microfluidics, the field that is shrinking genetic and chemistry laboratories to microchip sizes.

Financial analysts at Frost and Sullivan in New York City predict the microfluidics market is likely to reach $709.9 million by 2008.

"This could lead to unique ways to drive flows without requiring pumping," Smith said.

Charles Choi covers research and technology for UPI Science News.