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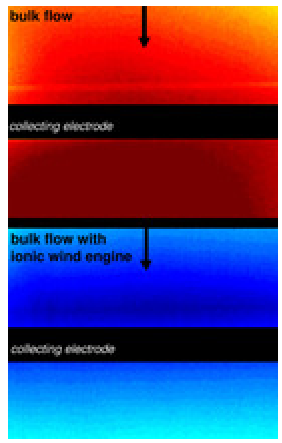
New technology has dramatic chip-cooling potential for future computers

WEST LAFAYETTE, Ind. - Researchers have demonstrated a new technology using tiny "ionic wind engines" that might dramatically improve computer chip cooling, possibly addressing a looming threat to future advances in computers and electronics.



Infrared images
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The Purdue University researchers, in work funded by Intel Corp., have shown that the technology increased the "heat-transfer coefficient," which describes the cooling rate, by as much as 250 percent.

"Other experimental cooling-enhancement approaches might give you a 40 percent or a 50 percent improvement," said Suresh Garimella, a professor of mechanical engineering at Purdue. "A 250 percent improvement is quite unusual."

When used in combination with a conventional fan, the experimental device enhanced the fan's effectiveness by increasing airflow to the surface of a mock computer chip. The new technology could help engineers design thinner laptop computers that run cooler than today's machines.

Findings are detailed in a research paper that has been accepted for publication in the Journal of Applied Physics and is tentatively scheduled to appear in the Sept. 1 issue. The paper was authored by mechanical engineering doctoral student David Go, Garimella, associate professor of mechanical engineering Timothy Fisher and Intel research engineer Rajiv Mongia.

"This technology is very exciting and innovative," Mongia said. "It has the potential of enabling imaginative notebook and handheld PC designs in the future."

Timothy Fisher (R) and Suresh

The new cooling technology could be

introduced in computers within three years if researchers are able to miniaturize it and make the system rugged enough, Garimella said. As the technology is further developed, such cooling devices might be integrated into portable consumer electronics products, including cell phones.

Advanced cooling technologies are needed to help industry meet the conflicting goals of developing more compact and lightweight computers that are still powerful enough to run high-intensity programs for video games and other graphics-laden applications.

"In computers and electronics, power equals heat, so we need to find ways to manage the heat generated in more powerful laptops and handheld computers," Fisher said.

Also involved in the research was undergraduate mechanical engineering student Raul Maturana, who was supported with a National Science Foundation fellowship.

The experimental cooling device, which was fabricated on top of a mock computer chip, works by generating ions - or electrically charged atoms - using electrodes placed near one another. The device contained a positively charged wire, or anode, and negatively charged electrodes, called cathodes. The anode was positioned about 10 millimeters above the cathodes. When voltage was passed through the device, the negatively charged electrodes discharged electrons toward the positively charged anode. Along the way, the electrons collided with air molecules, producing positively charged ions, which were then attracted back toward the negatively charged electrodes, creating an "ionic wind."

This breeze increased the airflow on the surface of the experimental chip.

Conventional cooling technologies are limited by a principle called the "no-slip" effect - as air flows over an object, the air molecules nearest the surface remain stationary. The molecules farther away from the surface move progressively faster. This phenomenon hinders computer cooling because it restricts airflow where it is most needed, directly on the chip's hot surface.

The new approach potentially solves this problem by using the ionic wind effect in combination with a conventional fan to create airflow immediately adjacent to the chip's surface, Fisher said.

The device was created at Purdue's Birck Nanotechnology Center in the university's Discovery Park. The researchers quantified the cooling effect with infrared imaging, which showed the technology reduced heating from about 60 degrees Celsius - or 140 degrees Fahrenheit - to about 35 degrees C, or 95 F.

"We've been trying to make this work for about a year, and now we have shown that it works quite well," Garimella said.

Patents are pending for the new design.

The researchers also have developed computational models to track the flow of electrons and ions generated by the device, information needed for designing future systems using the technology.

Computer chips are constantly being upgraded by creating designs with more densely packed circuits, transistors and other electronic components. The number of transistors per chip has been doubling every 18 months or so, in line with a general principle called Moore's law. As performance increases, however, so does heat generation, particularly in small hot spots. These hot spots not only hinder performance, but also could damage or destroy delicate circuitry. This means new cooling methods will be required for more powerful computers in the future.

The next step in the research will be to reduce the size of components within the device from the scale of millimeters to microns, or millionths of a meter. Miniaturizing the technology will be critical to applying the method to computers and consumer electronics, allowing the device to operate at lower voltage and to cool small hot spots, Garimella said.

Another challenge will be making the technology rugged enough for commercial applications.

"As things get smaller, they get more delicate, so we need to strengthen all the elements. And we believe we can achieve this goal in a year or so," Garimella said.

The researchers had previously authored two peer-reviewed papers about the work. Earlier work at Purdue to develop the ionic-wind technique has been supported by the National Science Foundation.

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Note to Journalists: An electronic copy of the research paper is available from Emil Venere, (765) 494-4709, venere@purdue.edu

PHOTO CAPTION:
These two infrared images show the cooling effect of an experimental device that uses small "ionic wind engines" developed at Purdue. The red image shows the hot surface of a mock computer chip heated to about 60 degrees Celsius (140 Fahrenheit), and the blue image demonstrates that the device was able to cool the surface to about 35 degrees Celsius (95 F). (Birck Nanotechnology Center image)

A publication-quality photo is available at http://news.uns.purdue.edu/images/+2007/garimella-ionic.jpg

PHOTO CAPTION:
Purdue mechanical engineers Timothy Fisher, at right, and Suresh Garimella, hold a silicon wafer containing experimental "ionic wind engines" being developed to cool computer chips. In research funded by Intel Corp., the engineers have demonstrated how the new technology might dramatically improve computer chip cooling for laptops and consumer electronics. Fisher and Garimella, both in Purdue's

School of Mechanical Engineering, are using the plasma enhanced chemical vapor deposition equipment shown here to make the devices sturdy enough for the rigors of everyday use in commercial products. (Purdue News Service photo/David Umberger)

A publication-quality photo is available at http://news.uns.purdue.edu/images/+2007/garimella-ionicwind.jpg

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ABSTRACT

Ionic Winds for Locally Enhanced Cooling

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Ionic wind engines can be integrated onto surfaces to provide enhanced local cooling. Air ions generated by field-emitted electrons are pulled by an electric field and exchange momentum with neutral air molecules, causing air flow. In the presence of a bulk flow, ionic winds distort the boundary layer, increasing heat transfer from the wall. Experiments demonstrate the ability of ionic winds to decrease the wall temperature substantially in the presence of a bulk flow over a flat plate, corresponding to local enhancement of the heat transfer coefficient by more than two-fold. Multiphysics simulations of the corona and flow describe the ability of the ionic wind to distort a bulk flow boundary layer and confirm the experimentally observed heat transfer enhancement trends.

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