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Compact cooler can chill computers

When you think of a tiny refrigerator and a university, you can quickly think of a small cube that could hold a frosty case of beer.

These days at Purdue University, they are thinking really small and are talking about a miniature refrigeration system small enough to fit inside laptops and personal computers. This cooling technology could boost performance while shrinking the size of computers.

Unlike conventional cooling systems, which use a fan to circulate air through finned devices called heat sinks attached to computer chips, miniature refrigeration would dramatically increase the amount of heat, said Suresh Garimella, the R. Eugene and Susie E. Goodson Professor of Mechanical Engineering at Purdue University.

The Purdue research focuses on learning how to design miniature compressors and evaporators, which are critical for refrigeration systems. The researchers developed an analytical model for designing tiny compressors that pump refrigerants using penny-size diaphragms and validated the model with experimental data. The elastic membranes consist of ultra-thin sheets of the plastic polyimide. They coat it with an electrically conducting metallic layer. The metal layer allows the diaphragm to move back and forth to produce a pumping action using electrical charges, or “electrostatic diaphragm compression.”

In related research, the engineers are among the first to precisely measure how a refrigerant boils and vaporizes inside tiny “microchannels” in an evaporator and determine how to vary this boiling rate for maximum chip cooling.

“We feel we have a very good handle on this technology now, but there still are difficulties in implementing it in practical applications,” said Garimella, director of the Cooling Technologies Research Center based at Purdue. “One challenge is that it’s difficult to make a compressor really small that runs efficiently and reliably.”

Computers will need new types of cooling systems as future computer chips will likely generate 10 times more heat than today’s microprocessors, especially in small “hot spots,” Garimella said.

Miniature refrigeration has a key advantage over other cooling technologies, said Eckhard Groll, a professor of mechanical engineering and fellow researcher.

“The best that all other cooling methods can achieve is to cool the chip down to ambient temperature, whereas refrigeration allows you to cool below surrounding temperatures,” he said.

The ability to cool below ambient temperature could result in smaller, more powerful computers, and it could improve reliability by reducing long-term damage to chips caused by heating.

One complication is the technology would require many diaphragms operating in parallel to pump a large enough volume of refrigerant for the cooling system.

“So you have an array of 50 or 100 tiny diaphragm compressors, and you can stack them,” Groll said.

The researchers conducted laboratory experiments with the diaphragms in Garimella’s Thermal Microsystems Lab, developed a computational model for designing the compressor, and validated the model with data from the lab. Findings showed it is feasible to design a prototype system small enough to fit in a laptop, Garimella said.

The model enables the engineers to optimize the design, determining how many diaphragms to use and how to stack them—parallel to each other or in series.

“If you stack in one direction, you get more pressure rise, and if you stack in the other direction, you get

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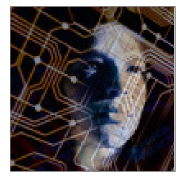

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more volume pumped," Groll said.

Learning how to manufacture the devices at low cost is another major challenge, with industry requiring a cost of about $30 each. "We can't currently produce them at this price, but maybe in the future," Groll said.

Another portion of the research focuses on learning precisely how refrigerant boils and turns into a vapor as it flows along microchannels thinner than a human hair. Such evaporators would go on top of computer chips.

Stefan S. Bertsch, the doctoral student who led work to set up experiments at the university's Ray W. Herrick Laboratories, saw how refrigerant boils inside the channels and measured how much heat transfers by this boiling refrigerant. He also created mathematical equations needed to properly design the miniature evaporators.

"This overall project represents the first comprehensive research to carefully obtain data showing what happens to heat transfer in arrays of microchannels for miniature refrigeration systems and how to design miniature compressors," Garimella said. "Eventually, we will be able to design both the miniature compressors and evaporators."

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