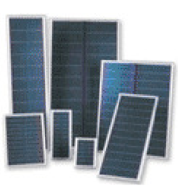

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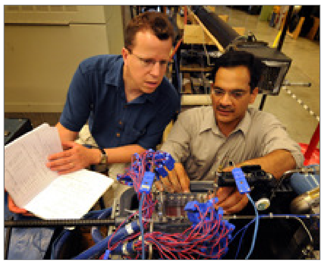

Researchers at Purdue are developing a miniature refrigeration system small enough to fit inside laptops and personal computers, a cooling technology that would boost performance while shrinking the size of computers. The researchers collect data using a myriad of sensors to precisely measure how a refrigerant boils and vaporizes inside tiny "microchannels" in a part of the refrigeration system called an evaporator. Data are needed to determine how to vary this boiling rate for maximum chip cooling. Eckhard Groll, at left, a professor of mechanical engineering, and Suresh Garimella, the R. Eugene and Susie E. Goodson Professor of Mechanical Engineering, discuss the microchannel data at the Ray W. Herrick Laboratories. (Purdue News Service photo/David Umberger)

Abstract:

ABSTRACT

Analytical Model for an Electrostatically Actuated Miniature Diaphragm Compressor

Abhijit A Sathe, Eckhard A Groll and Suresh V Garimella

NSF Cooling Technologies Research Center, School of Mechanical Engineering, Purdue University

This paper presents a new analytical approach for quasi-static modeling of an electrostatically actuated diaphragm compressor that could be employed in a miniature scale refrigeration system. The compressor consists of a flexible circular diaphragm clamped at its circumference. A conformal chamber encloses the diaphragm completely. The membrane and the chamber surfaces are coated with metallic electrodes. A potential difference applied between the diaphragm and the chamber pulls the diaphragm toward the chamber surface progressively from the outer circumference toward the center. This zipping actuation reduces the volume available to the refrigerant gas, thereby increasing its pressure. A segmentation technique is proposed for analysis of the compressor by which the domain is divided into multiple segments for each of which the forces acting on the diaphragm are estimated. The pull-down voltage to completely zip each individual segment is thus obtained. The required voltage for obtaining a specific pressure rise in the chamber can thus be determined. Predictions from the model compare well with other simulation results from the literature, as well as to experimental measurements of the diaphragm displacement and chamber pressure rise in a custom-built setup.

ABSTRACT

Refrigerant Flow Boiling Heat Transfer in Parallel Microchannels as a Function of Local Vapor Quality

Stefan S. Bertsch a,b, Eckhard A. Groll a,b, Suresh V. Garimella b,*

a Ray W. Herrick Laboratories, School of Mechanical Engineering, Purdue University

b Cooling Technologies Research Center, School of Mechanical Engineering, Purdue University

Flow boiling of refrigerant HFC-134a in a multi-microchannel copper cold plate evaporator is investigated. The heat transfer coefficient is measured locally for the entire range of vapor qualities starting from subcooled liquid to superheated vapor. The test piece contains 17 parallel, rectangular microchannels (0.762 mm wide) of hydraulic diameter 1.09 mm and aspect ratio 2.5. The design of the test 13 facility is validated by a robust energy balance as well as a comparison of single-phase heat transfer coefficients with results from the 14 literature. Results are presented for four different mass fluxes of 20.3, 40.5, 60.8, and 81.0 kg m[1]2 s[1]1, which correspond to refrigerant 15 mass flow rates of 0.5-2.0 g s[1]1, and at three different pressures 400, 550 and 750 kPa corresponding to saturation temperatures of 8.9, 16 18.7, and 29 [1]C. The wall heat flux varies from 0 to 20 W/cm2 in the experiments. The heat transfer coefficient is found to vary significantly with refrigerant inlet quality and mass flow rate, but only slightly with saturation pressure for the range of values investigated. The peak heat transfer coefficient is observed for a vapor quality of approximately 20%.

Tiny refrigerator taking shape to cool future computers

WEST LAFAYETTE, IN | Posted on June 19th, 2008

Researchers at Purdue University are developing a miniature refrigeration system small enough to fit inside laptops and personal computers, a cooling technology that would 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 how much heat could be removed, said Suresh Garimella, the R. Eugene and Susie E. Goodson Professor of Mechanical Engineering.

The Purdue research focuses on learning how to design miniature components called 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 are made of ultra-thin sheets of a plastic called polyimide and coated with an electrically conducting metallic layer. The metal layer allows the diaphragm to be moved 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.

The research is led by Garimella and Eckhard Groll, a professor of mechanical engineering.

"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."

Findings will be detailed in two papers being presented during the 12th International Refrigeration and Air Conditioning Conference and the 19th International Compressor Engineering Conference on July 14-17 at Purdue. The papers were written by doctoral students Stefan S. Bertsch and Abhijit A. Sathe, Groll and Garimella.

New types of cooling systems will be needed for future computer chips that 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, Groll said.

"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 also could improve reliability by reducing long-term damage to chips caused by heating.

One complication is that 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 that 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, either 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 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 be placed on top of computer chips.

Bertsch, the doctoral student who led work to set up experiments at the university's Ray W. Herrick Laboratories, observed how refrigerant boils inside the channels and measured how much heat is transferred 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."

Some of the research was performed at the Birck Nanotechnology Center in Purdue's Discovery Park.

The research is funded by the Purdue-based National Science Foundation Cooling Technologies Research Center, a consortium of corporations, university and government laboratories working to overcome heat-transfer obstacles in developing new, compact cooling technologies. Groll's research is based at Herrick Laboratories.

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For more information, please click here

Contacts:
Writer:
Emil Venere
(765) 494-4709
venere@purdue.edu

Sources:
Eckhard Groll
(765) 496-2201
groll@ecn.purdue.edu

Suresh Garimella
(765) 494-5621
sureshg@ecn.purdue.edu

Purdue News Service:
(765) 494-2096
purduenews@purdue.edu

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