Cooling Technologies Research Center (CTRC)

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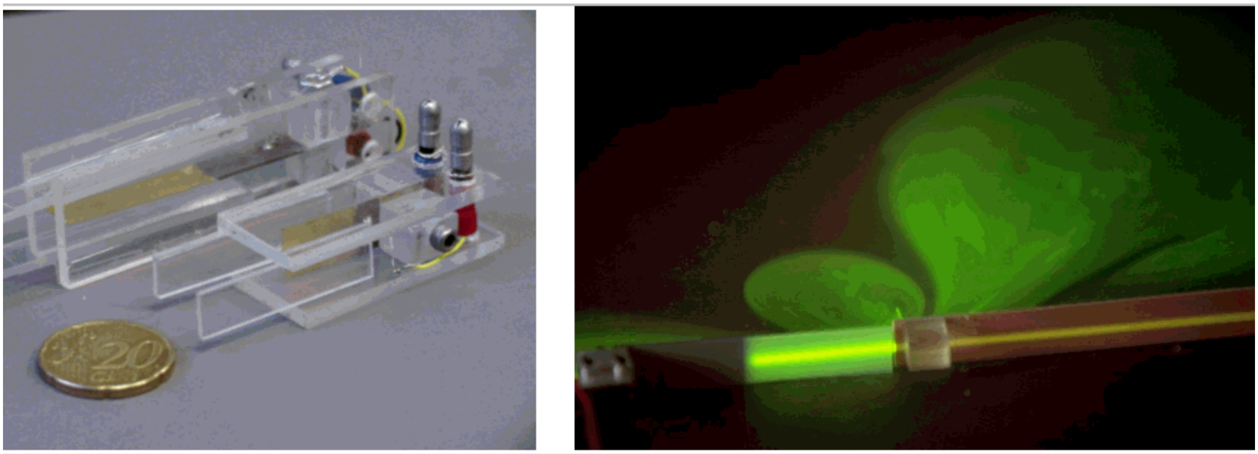
Miniature Piezoelectric Fans

Innovative, miniature piezoelectric fans have been developed in this CTRC project (by Arvind Raman and Suresh Garimella) into a viable technology for meeting a variety of cooling needs in portable and small-scale electronic devices. These fans are small, noiseless, extremely low-power devices, and can easily be fabricated to suit specific applications. They are very well suited to providing supplemental cooling in hot spots and other stagnant areas in devices such as laptops and cell phones where rotary fan action is ineffective. In smaller devices, where rotary fans are not practical and electronics are pushed to the limits of their heat dissipation capacities, piezoelectric fans offer the only realistic cooling solution while meeting the noise and power constraints of portable devices. Analytical tools have been developed for modeling the flow field, heat transfer, and fan structure; flow-structure interaction is currently being investigated, to allow the design of optimal cooling systems. For more information, contact Suresh Garimella, 765-494-5621; sureshg@ecn.purdue.edu.



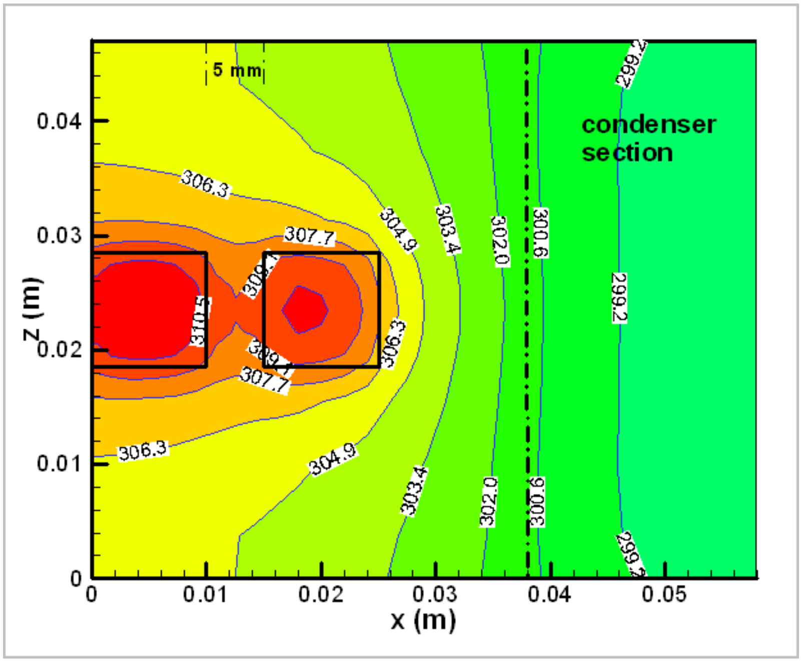
Above: The fans and the visualized flow around it.

Microchannel Heat Sinks

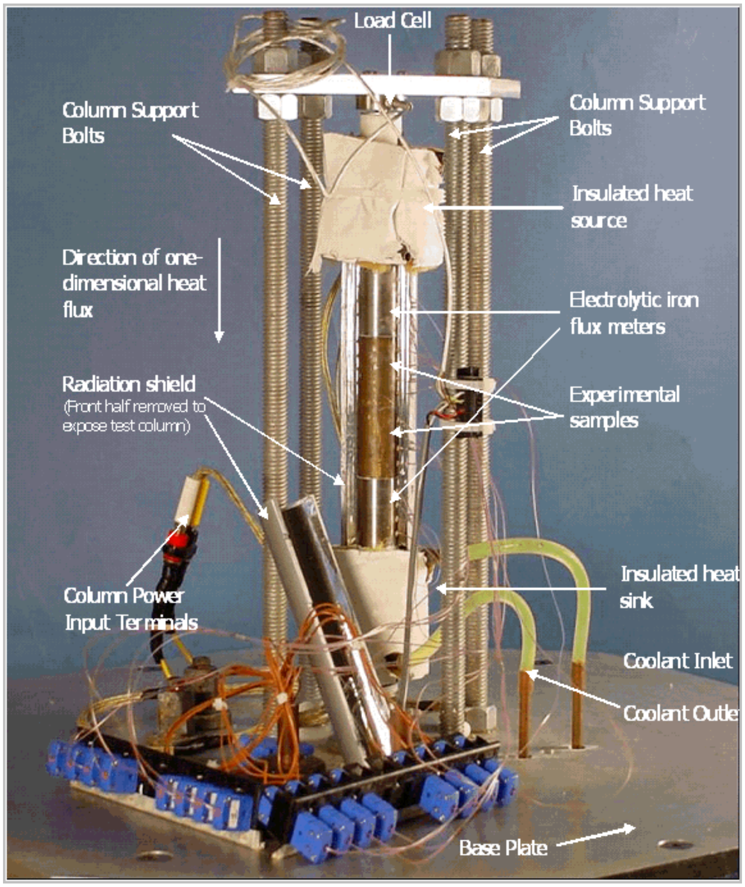
Major strides are being made in this CTRC project in better understanding transport in microchannels, and hence in rendering microchannel heat sinks implementable in electronics cooling applications. Several novel experimental and modeling tools have been developed. Infrared Particle Image Velocimetry (IR-PIV) is being developed as a tool to make measurements inside silicon microstructures (with no optical access), capitalizing on the transparency of silicon to infrared light; this work is a collaboration between Suresh Garimella and Steve Wereley. Accurate velocity measurements are currently possible (from images like the IR photograph which shows tracers flowing through a microchannel) with this technique, and it is being extended to measuring temperatures inside such flows. Boiling in microchannel heat sinks is currently under investigation using this technique. System-level analysis of microchannel cooling systems, with an emphasis on design for energy efficiency and manufacturability, is now possible through a software tool developed in the Center. For more information, contact Suresh Garimella, 765-494-5621; sureshg@ecn.purdue.edu.

Miniature Flat Heat Pipes

A first-of-its-kind sophisticated model has been developed through this CTRC project for three-dimensional, transient analysis of non-conventional heat pipe designs for low-form-factor applications in electronics packaging. The software package allows for the design and optimization of heat pipes for operation with multiple, discrete heat sources mounted on the heat pipe; sample temperature contours under two chips mounted on a flat heat pipe are shown in the figure on the rights. The model predictions have been validated against experimental measurements. The model is being used to investigate issues in the miniaturization of heat pipes, including improved wick structures and heat pipe layouts. This project is a collaboration between Suresh Garimella and Jayathi Murthy. For more information, contact Suresh Garimella, 765-494-5621; sureshg@ecn.purdue.edu.



Prediction and Mitigation of Thermal Contact Resistance



A comprehensive, combined theoretical and experimental investigation has led to the development of a validated model and associated software for the prediction of thermal contact conductance at interfaces in electronics cooling applications at low loads. Contact resistance at different interfaces is a ubiquitous problem in such applications, and can often present the primary resistance to heat flow in an electronics package. The software model allows for better prediction of contact resistance, and compares well with experimental data (obtained from the custom-built facility shown). It can easily be applied to any interface if the material properties are known and profile scans of the surfaces are available. The program combines three sub-models for constriction resistance, surface deformation, and surface characterization into the first contact conductance model of its kind, generally applicable to any flat metallic surface regardless of mode of deformation, gas gap conductivity, or resolution of the scanning instrument used.

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Phase Change Energy Storage For Transient Power Dissipation

Thermal transients occur in power semiconductors and electronics due to the current in-rush while starting a motor, in inductive devices such as heaters and transformers, in capacitive charging, and in power grid management. The suppression of temperature overshoots during the dissipation of transient power spikes is an important challenge in electronics package design. As an alternative to using solid metal heat sinks to absorb the thermal transients from these power spikes, this CTRC project has investigated energy storage into a phase change material (PCM) as an alternative. A versatile software package, easy-to-use analytical formulae, and experimental demonstrations of the use of a PCM storage unit have led to designs that results in lower junction temperatures while at the same time yielding weight and volume savings. Temperature and velocity fields in a PCM storage unit under the action of pulsed heating of three discrete components mounted on the bottom are shown. The photograph is of a simulated unit with a transparent PCM melting from the left, with the calculated interface shape superimposed. Other novel designs of heat sinks exploiting fins and foams impregnated with PCMs are currently being explored. For more information, contact Suresh Garimella, 765-494-5621; sureshg@ecn.purdue.edu.