Micro-Pin Fin Heat Sinks

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Primary CNF Tools Used: AJA sputter deposition, Oxford PECVD, AJA ion mill, Oxford 81 etcher, FilMetrics film measurement systems, general chemistry hoods, Zeiss Ultra SEM, SÜSS MA6-BA6 contact aligner, ABM contact aligner, laser cutter, general SU-8, general lithography, SÜSS bonder, dicing saw

Abstract:

Micro-Pin fin heat sink with single-phase and two-phase flows have received considerable attention as a viable passive cooling technique to address emerging challenges in the thermal management of ultra-high-power electronic components. In the current study, a series of MEMS devices with various pin fin geometries and configurations were micro-fabricated to study single-phase and two-phase flow heat transfer. The micro-devices consist of three substrates: two 500 μm glass and 200 μm SU-8 layer as a microchannel that was sandwiched between the glass layers. For pin fin tip clearance study, two SU-8 layers were put on top of each other to form the required tip gaps. All the materials are transparent to allow flow visualization. In addition to that, thermal conductivities of all the substrates are very low resulting in minimized conduction heat losses during experiments. Distilled water was used in an open fluidic loop and pressure difference was utilized to drive the flow. A conjugated flow and heat transfer numerical model showed a good agreement with the measurements and revealed the details of flow structure downstream pin fins. Vortical flow structures were linked to local temperature measurements and heat transfer enhancement.

Summary of Research:

The ever-increasing electronic chip power density necessitates implementing novel cooling technologies capable of dissipating heat at a much higher rate. The presence of pin fins in heat sinks triggers local turbulence, initiates vortical flows and vortex shedding all of them promote heat transfer [1,2]. The aim of this study is to utilize novel microelectromechanical systems (MEMS) devices, advanced measurements techniques and accurate numerical simulations for studying single/two-phase fluid flow and heat transfer at micro pin fin heat sinks (Figure 1). Measuring heat transfer coefficient at microscale is often accompanied by inherent uncertainties caused by average temperature data.

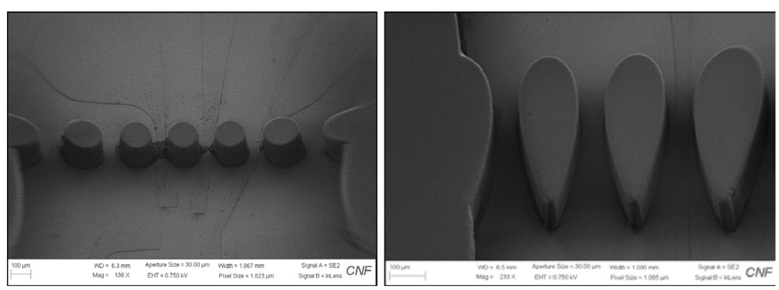

Figure 1: Scanning electron microscopy (SEM) images of circular (left) and hydrofoil (right) pillars.

This study uses the state-of-the-art transparent microdevices with the capability of high-resolution local temperature measurements- In addition to that, a novel technique to synchronize two-phase flow visualization with data acquisition combined with local temperature measurement reveal sophisticated two-phase flow physics such as cavitation and boiling regimes. Concurrently, a high-fidelity CFD scheme to simulate conjugate conduction/forced convection phenomena developed to estimate local heat transfer coefficients. While prior studies shed light on cavitation downstream pin fins in microchannel [3,4], this study investigates the heat transfer processes in presence of hydrodynamic cavitation.

The micro-devices (Figure 1) were fabricated in the Cornell NanoScale Science and Technology Facility (CNF). First, heater and resistance temperature detectors (RTDs) were deposited on a Pyrex® Borofloat® wafer. This step was performed using various tools such as AJA deposition, lithography, contact aligners, dry etching with AJA ion mill and Oxford etcher 81, wet etching using BOE and aluminum etchant, etc. Heater and RTDs were made of platinum with a thin layer of titanium underneath to enhance adhesion to Pyrex. A total of five masks were used to create heater and RTDs on the Pyrex. Microchannel and pin fins were formed on the heater substrate using a negative permanent photoresist called SU-8. Since Pyrex has low thermal conductivity, the challenge was to prevent the wafer to bow during long hours of backing. Hence, a custom-made recipe was developed. The microchannel pattern was created using ABM contact aligner with long hours of ultraviolet ray exposures. The next step was to seal the microchannel top with another Pyrex wafer. To do so, a special sticker was used to bond the two layers.

The micro devices then were diced using dicing saw. A custom-designed package was fabricated to provide fluidic connections to the microchannel and to secure the MEMS devices.

A fluidic loop with water and HFE 7000 was constructed and the package was placed in the loop. Using a custom-made PCB and spring-loaded probes, the heater in the microchannel was wired to a power supply. Joule heating process causes the heater to generate heat. RTDs were placed in several locations and measured wall temperature while flow was passing through the microchannel. The presence of pin fin alters flow structures and effects downstream heat transfer process. In two-phase experiments, boiling regimes were captured and analyzed.

A numerical model capable of predicting conjugate fluid and heat transfer phenomena was developed. The model revealed vortical flow in the microchannel and enabled linking heat transfer process and flow structure.

We successfully fabricated MEMS devices with various pin fin configurations and carried out experiments. We are currently analyzing our data and compare it with the numerical simulations.

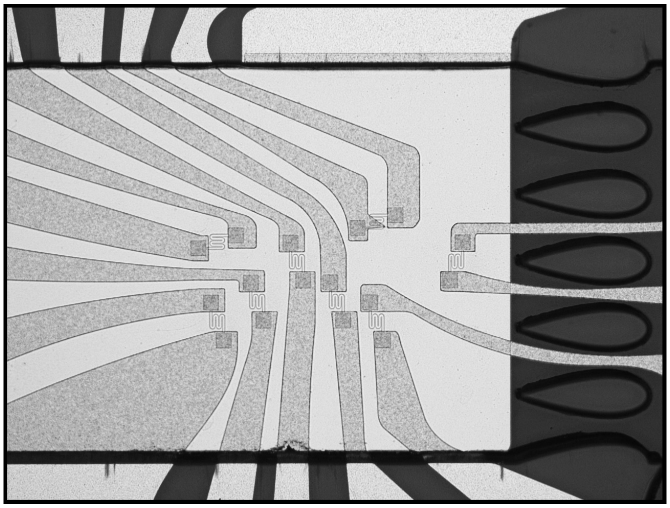

Figure 2: Microscopic image of hydrofoil array with pin fins, RTDs and electrical vias.

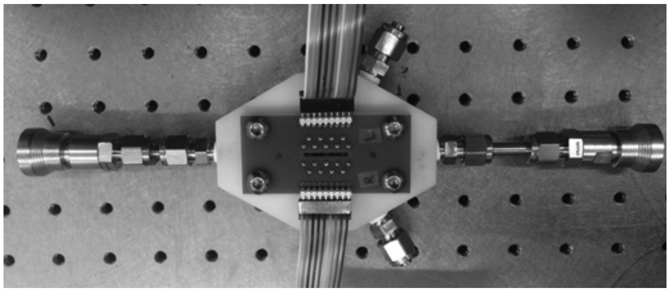

Figure 3: Package with external electrical connections.

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References:

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