Single-phase Modeling in Microchannel with Piranha Pin Fin

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Overview

Motivation

Methodology

Results and discussion

Summary and ongoing work
Motivation
Feeling the heat

“The more that microcircuits are shrunk, the hotter they get. Engineers are on the hunt for ways to cool off computing.”

Steam carries heat away from Google's data centre in Dalles, Oregon.

Challenges of cooling

Radar system

Medical system
MRI

Lighting
Methodology
How to meet cooling challenges

Heat dissipation

Air cooling

Liquid cooling
  - Single-phase
  - Flow boiling

Microchannel
  - Small dimension
  - High surface/volume ratio

Tuckerman and Pease, 1981, microchannel, 800 W/cm²
Piranha pin fin

- Cavity for nucleation site
- Bubbles departure
- Pin fin increases heat transfer area
- Recirculation zone
- Vapor is vented out
Apparatus

BOROFLOAT GLASS

SILICON SUBSTRATE

HEATING ELEMENT

STAINLESS COVER PLATE

MEMS DEVICE

DELRIN MICRODEVICE PACKAGE

ELECTRICAL SPRING PROBES

DELRIN PROBE PLATE
Apparatus

Working fluid: HFE7000
Results and discussion
Experimental measurement

Working fluid HFE 7000; $T_{\text{sat}}=77^\circ\text{C}$; $G_{\text{in}}=474 \text{ kg/m}^2$; open flow
Single-phase set up

- Conjugate heat transfer
- Laminar flow
- Heat transfer in solid & fluid
Pressure drop

![Graph showing pressure drop over G in (kg/m²s)]
Temperature

$G_{in} = 948 \text{ kg/m}^2\text{s} \text{ open flow}$

![Graph showing the relationship between temperature ($T_w$) and heat flux ($q''$) with data points for $T_{ave\_Device\_7\_exp}$ and $T_{ave\_Device\_7\_sim}$.](image)
Temperature

$G_{in} = 2460 \text{ kg/m}^2\text{s}$  open flow

- $T_{ave\_Device\_7\_exp}$
- $T_{ave\_Device\_7\_sim}$

![Graph showing temperature vs. heat flux for different conditions.](image-url)
Analysis

$V (\text{m/s})$

$T (\text{K})$

335
330
325
320
315
310
305
300
295
290
Analysis

Streamlines

[Temperature contour plots with temperature range from 305 to 333 K.]

[Temperature contour plots with temperature range from 325 to 333 K.]
Average surface temperature $T_w$

![Graph showing the relationship between $q''$ (W/cm²) and $T_w$ (°C).](image)

Single phase  Two phase

Working fluid HFE 7000; $T_{sat} = 77°C$; $G_{in} = 474$ kg/m²; open flow
Heat transfer coefficient $h$

- Single phase
- Two phase

1.68 times single-phase $h$
$q = 160 \text{ W/cm}^2$
Bubbly flow

$q = 255 \text{ W/cm}^2$
Bubble coalescence and attached to sidewall

$h$ (kW/m²K)

$q''$ (W/cm²)

Single phase

Flow boiling
2D Two-phase modeling

- Void fraction
- Velocity
- Temperature

T=0 s  T=3E-5 s  T=6E-5 s
Summary and on going work

• Single-phase heat transfer has been studied with experiments and simulation
• Pin fins can realize heat dissipation effectively.
• Optimization of $PPFs$ is ongoing.
• Two-phase modeling is ongoing.
Thank you