Towards Integration of NEPCM and Microfluidics for Microelectronics Cooling

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Research Motivation

- Microelectronic devices such as laptop computers generate heat
- With increasing functionality, microelectronic devices require more heat dissipation
- Current integrated heat dissipation methods are reaching their limits
- External cooling is state-of-the art but non-ideal
Motivation for Microfluidics (Microchannels)

- Suited for chip or package level cooling
- Small length scales for higher heat transfer rates
- Forced convection using liquid for higher heat transfer rates

Liquid flows through channels

NEPCM

Motherboard
Energy Storage Technologies

Storage of energy is required for managing any form of renewable sources of energy.

Thermal Energy is abundant: solar radiation, geothermal, stratified layers in oceans.

Released during most energy conversion processes; widely labeled as "waste heat".
Sensible & Latent Heat Storage

- **Sensible** heat storage is realized by heating/cooling a material without any phase alteration (heat capacity).

- **Latent** heat storage takes advantage of the latent enthalpy (of fusion) of a material during solid-liquid phase transformation.

- Advantages of the *Phase Change Materials (PCM)* are:
  - Small temperature variation (nearly isothermal)
  - Higher energy density

![Diagram showing 1 kg of ICE with 330 kJ of energy equivalent to 8 kg of WATER over 10°C]
Thermal Energy Storage by Phase Change Materials (PCM)
Desired Properties of PCM

- High Heat of Fusion
- High Thermal Conductivity
- High Density
- High Specific Heat
- Low Volume Change
- Low Vapor Pressure
- Chemical Stability in response to exposures
- Cycling Stability \((1 - 10^3)\)
- Little Supercooling
- Compatibility with Container Material
- Low Cost
- Recyclability
Thermal Conductivity Enhancers

PCM enhanced by meso- to micro-scale fillers, e.g., metal fins/foams, and carbon fibers

Fixed Structures or Form-Stable

Nano-enhanced PCM (NEPCM)

Free-Form COLLOIDS

Nano-scale Structures

Apparent Thermal Conductivity of PCM “Composites”

k = 0.2 W/m°C

PCM (Liquid)

1 ~ 10 mm micron range
Advantages over **Form-Stable** Composites

- Lighter weight
- Can be encapsulated
- Higher latent heat (no voids in liquid phase)
- Due to “fluidity”, forced/natural convection can enhance heat transfer further
- No “contact heat transfer” issues
- Straightforward recycling
The University of Alabama
Nanoparticles Separation and Reclamation

Auburn University
- NEPCM Development and Characterization
- Modeling and Testing
- Nanoparticle-Enhanced Lubricating Properties of Paraffinic Oils

University of South Alabama
Thermal Conductivity and Heat Dispersion Effect

Tuskegee University
NEPCM in Package Level Micro Electronics Cooling

Auburn University
Montgomery
Multi-Scale, Multi-Physics Non-Continuum Modeling
Experimental Station

- Insulated Bare Bar
- Bare Bar
- Cartridge Heater
- Multimeter or Data Acquisition System
- Power Supply
- Thermocouple
## Summary and Outlook

<table>
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<tr>
<th>Method</th>
<th>$\Delta T$ (°C)</th>
<th>Power (W)</th>
<th>Space</th>
<th>Noise</th>
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<td>0</td>
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<td>N/A</td>
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<tr>
<td>MCs</td>
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<td>varies</td>
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<td>Fan</td>
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</table>

**Going forward…**

- Test other nanoparticles such as carbon nanotubes ($k > 1000 \text{ W/m} \cdot \text{°C}$)
- Evaluate salt hydrate PCM
- Integrate microfluidics and NEPCM
Acknowledgements

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Questions?