Towards Integration of NEPCM and Microfluidics for Microelectronics Cooling

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TUSKEGEE UNIVERSITY

Outline

- Research Motivation
- Background on Energy Storage and NEPCM
- AL Research Cluster
- Microelectronics Cooling Experiments
- Summary and Outlook
- Acknowledgements

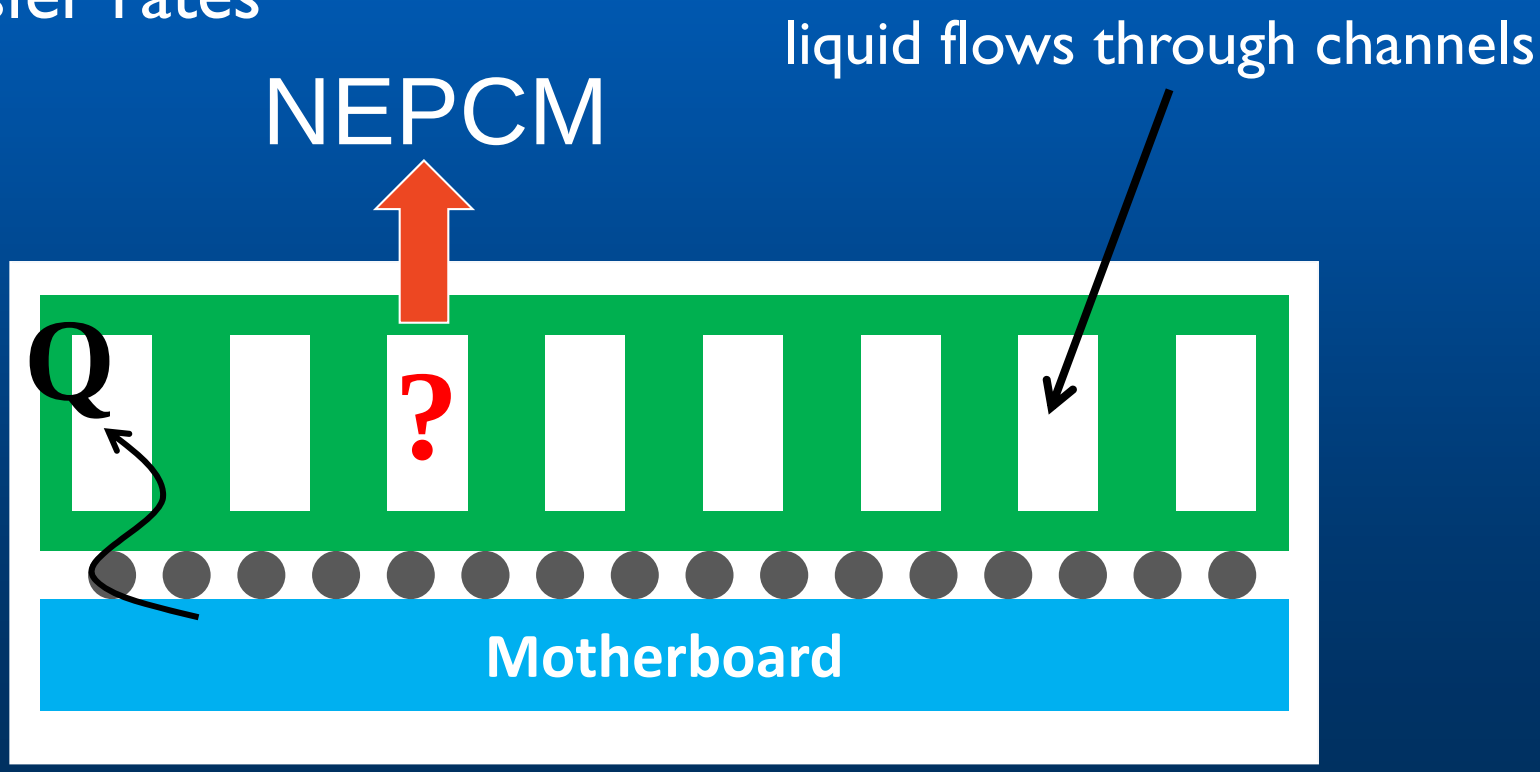
Research Motivation

- Microelectronic devices such as laptop computers generate heat
- With increasing functionality, microelectronic devices require more heat dissipation
- Current **<u>integrated</u>** heat dissipation methods are reaching their limits
- External cooling is state-of-the art but non-ideal

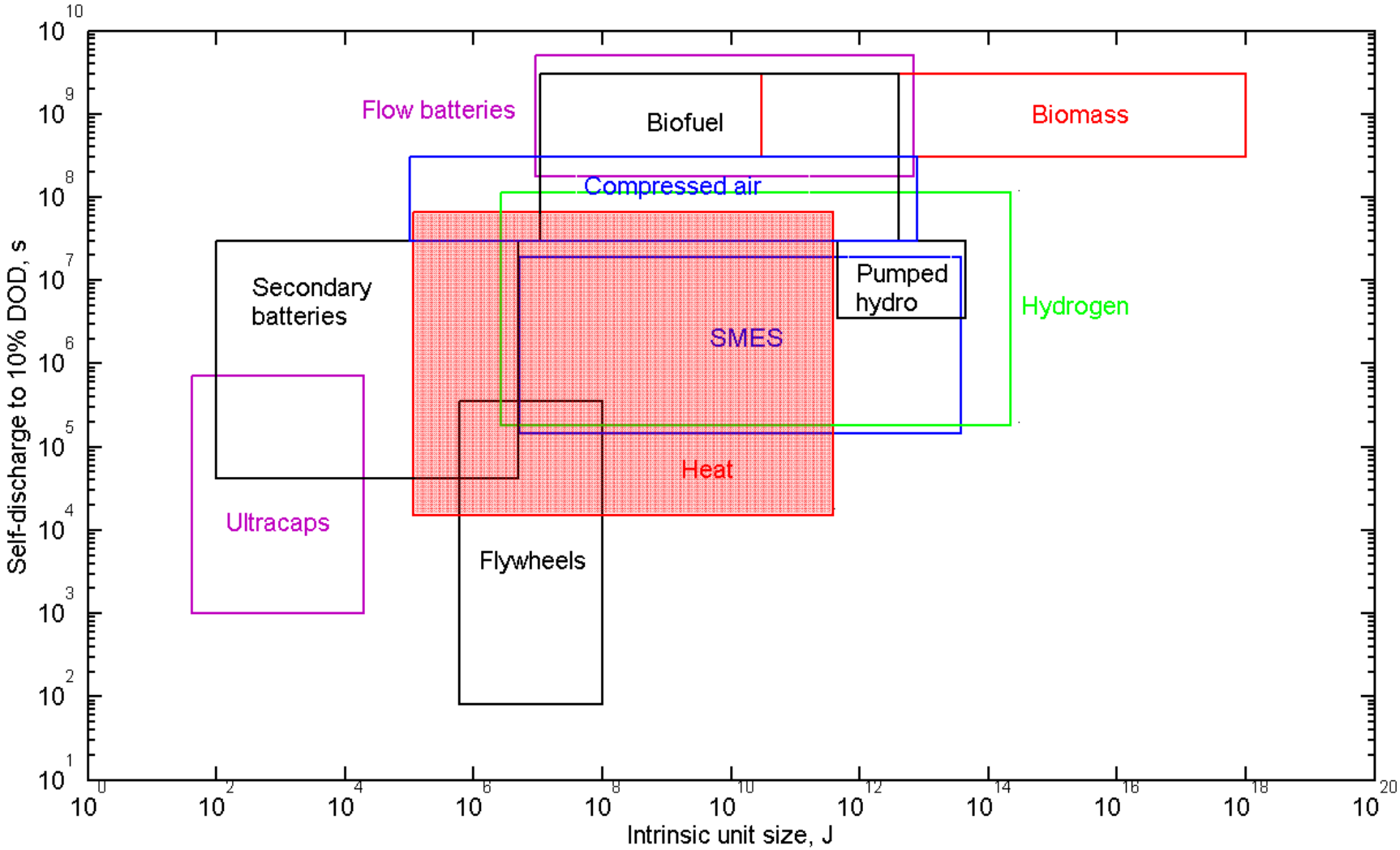
Laptop External Cooling Device

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

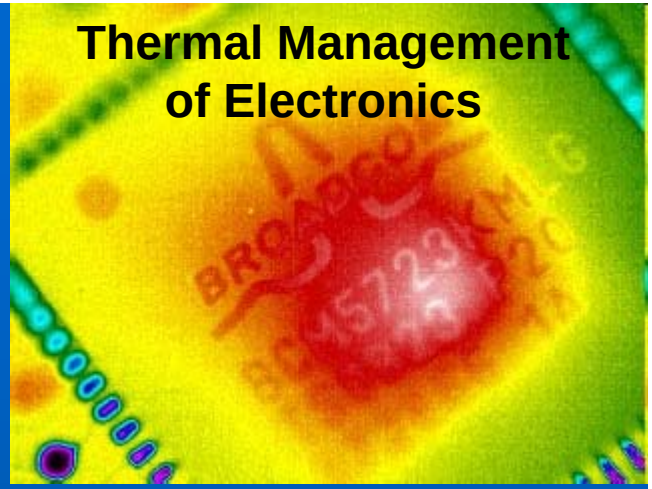


Energy Storage Technologies

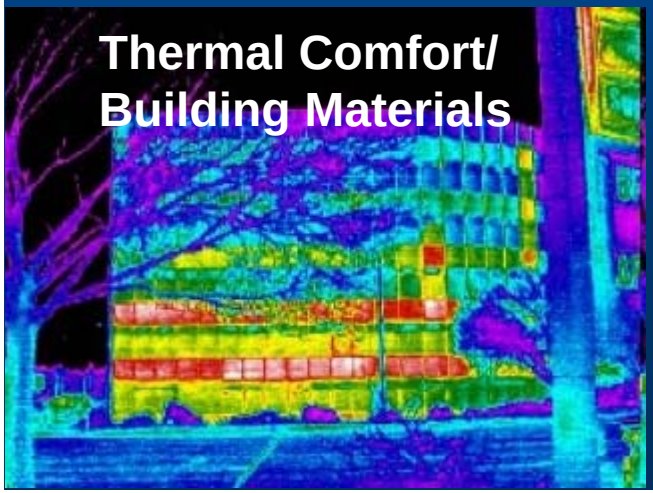


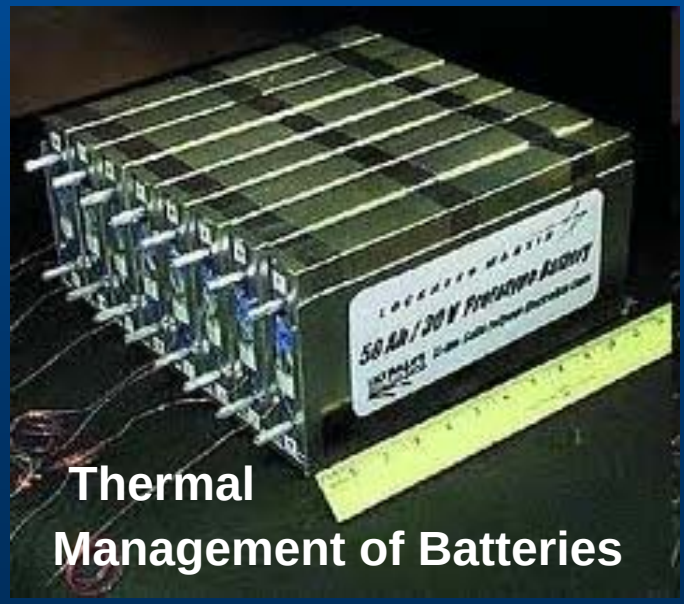
Source: R. Hammerschlag and C. P. Schaber, "Energy Storage Technologies," in Energy Conversion, Edited by D. Y. Goswami and F. Kreith, Chapter 15, CRC Press, pp. 15-1 to 15-22, 2008.

Motivation for Storage of Thermal Energy



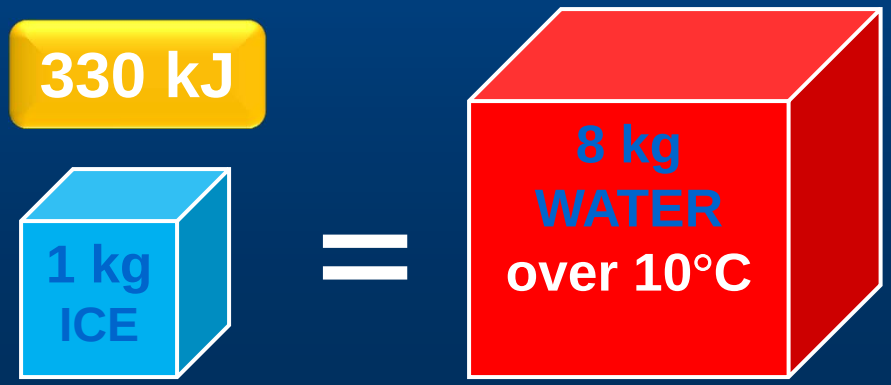
- Storage of energy is required for managing any form of renewable sources of energy
- Thermal Energy is abundant: solar radiation, geothermal, stratified layers in oceans.
- Released during most energy conversion processes; widely labeled as *"waste heat"*



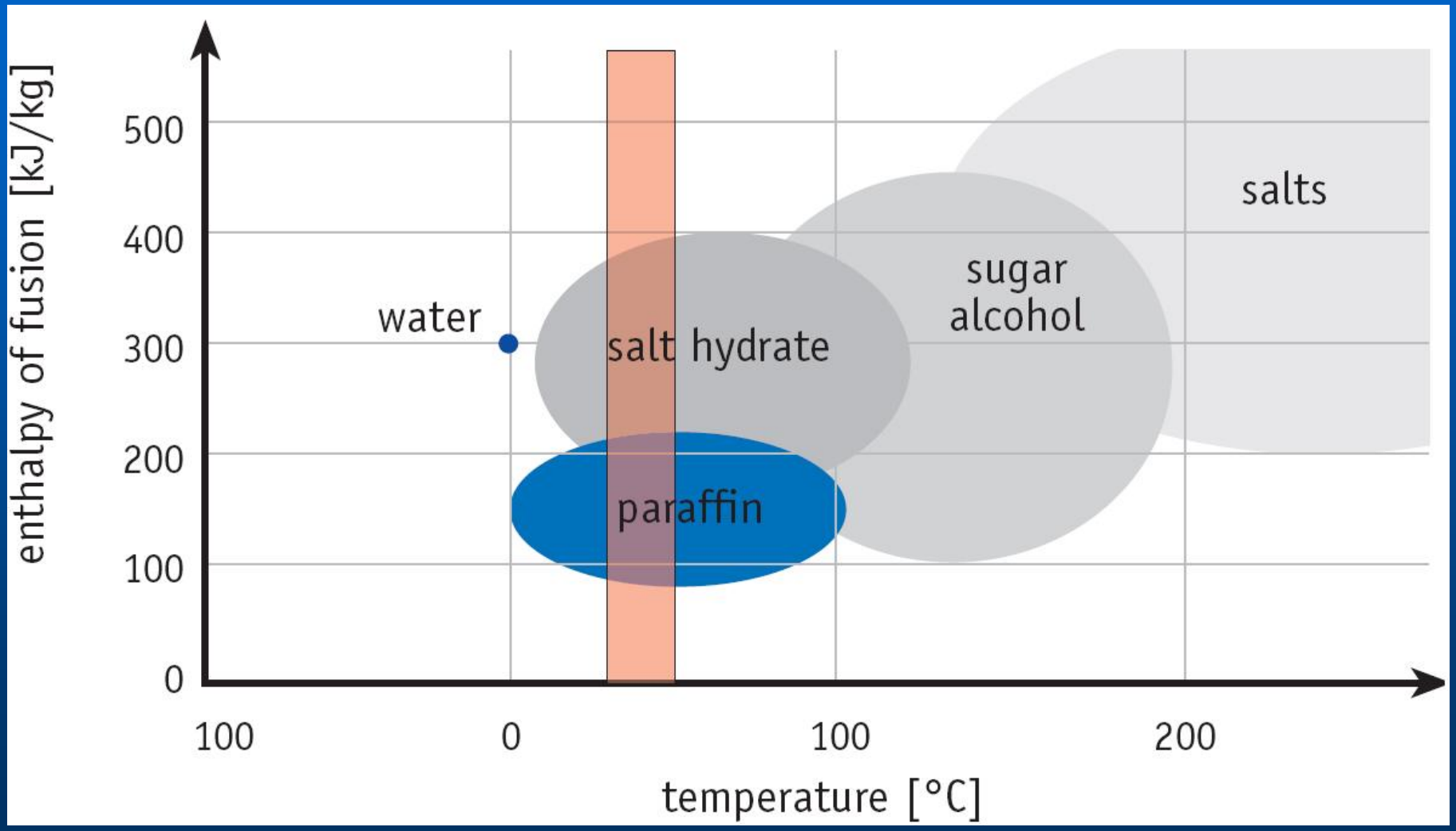


Sensible & Latent Heat Storage

- 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



Thermal Energy Storage by Phase Change Materials (PCM)

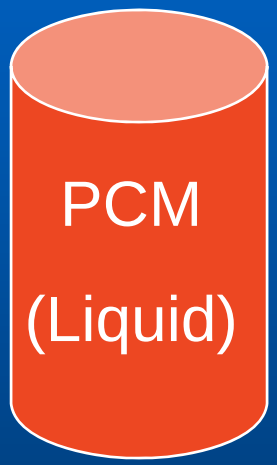


Desired Properties of PCM

- 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

k = 0.2 W/m°C



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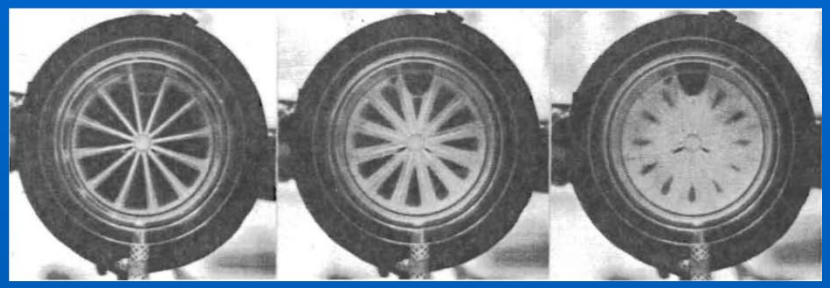
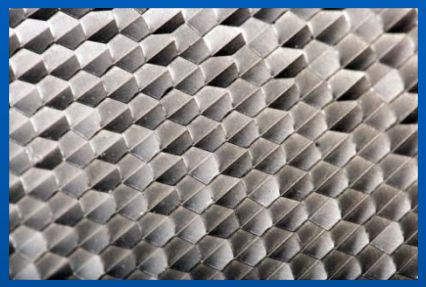
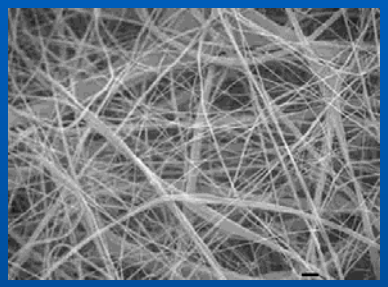




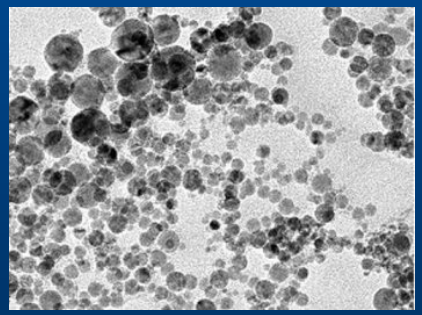


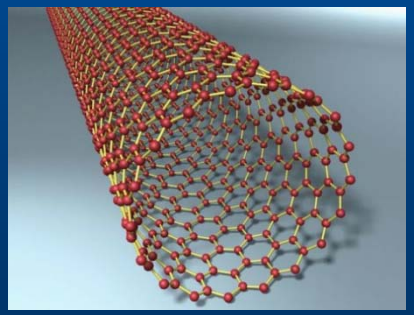
1 ~ 10 mm micron range

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

Fixed Structures

or **Form-Stable**



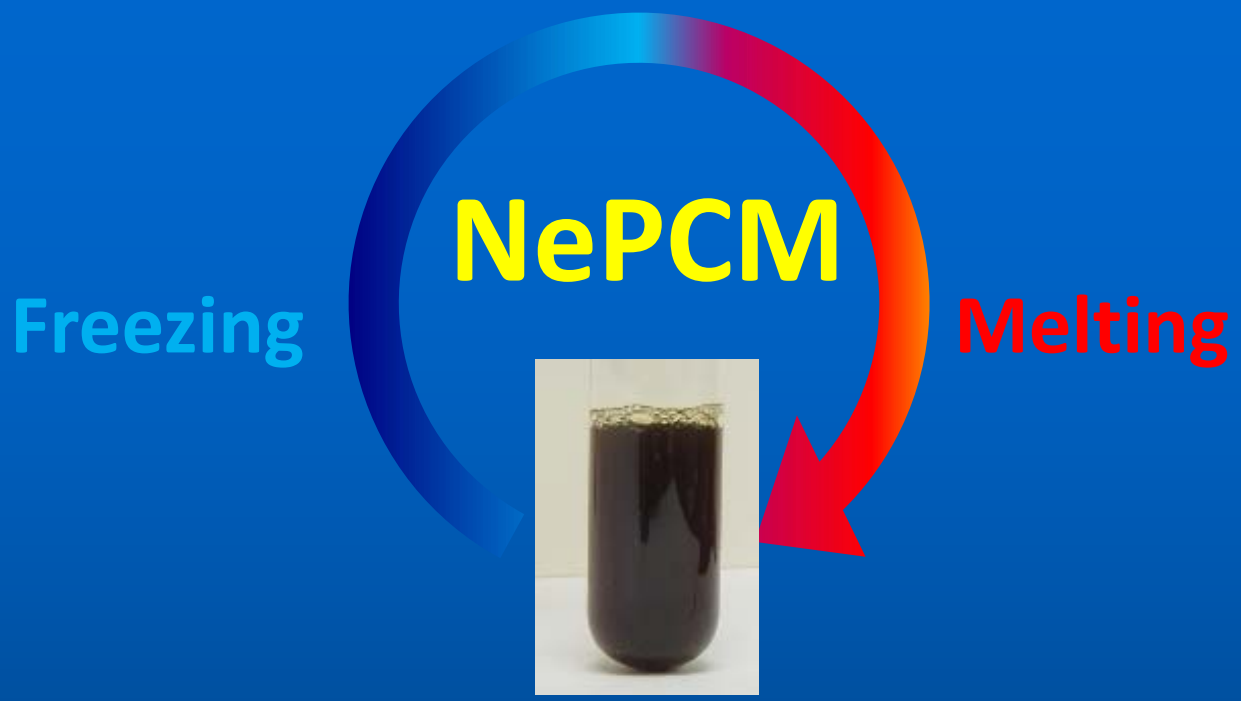


Nano-enhanced PCM (**NEPCM**)

Free-Form COLLOIDS

Nano-scale Structures

Apparent Thermal Conductivity of PCM "Composites"



Advantages over **Form-Stable** Composites

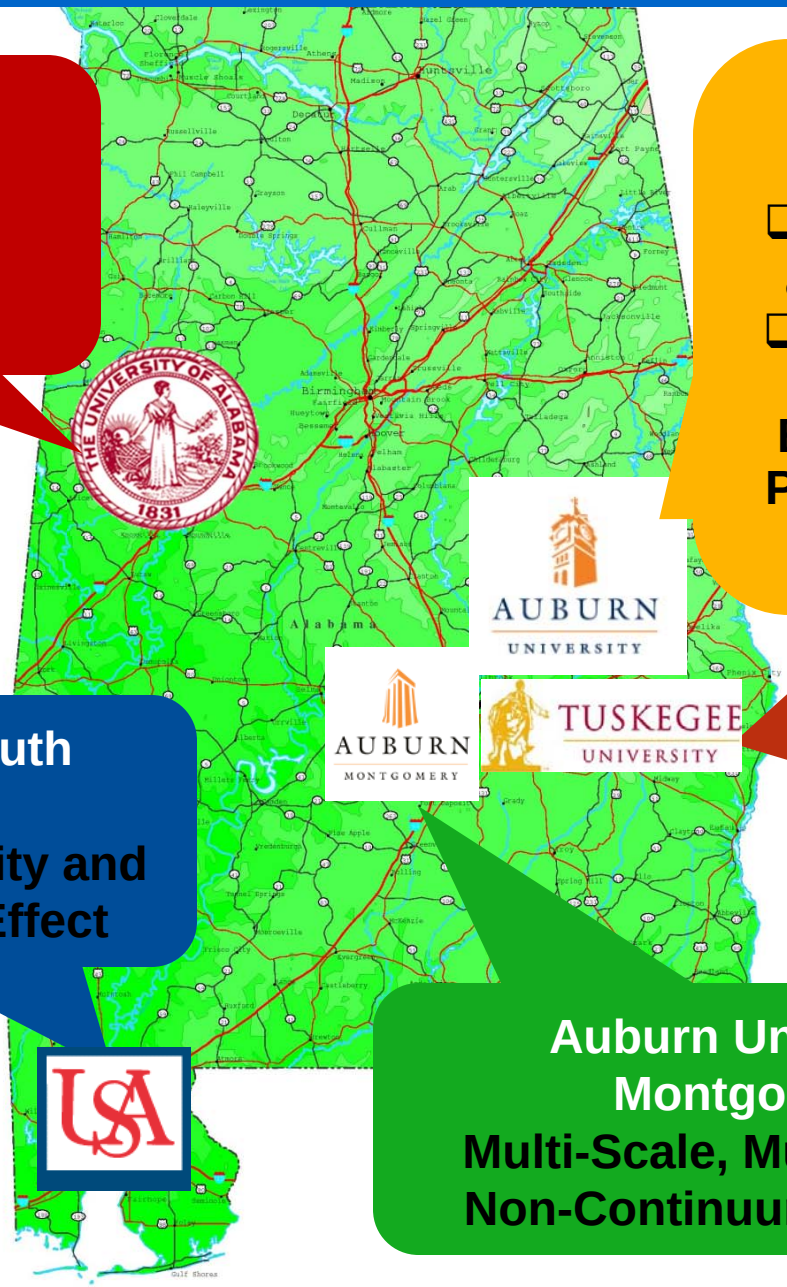
- Lighter weight
- Can be encapsulated
- Higher latent heat (no voids in liquid phase)
- Due to “fluidity”, forced/natural convection can enhance heat transfer further
- No “contact heat transfer” issues
- Straightforward recycling

AL NEPCM Cluster (Led by Khodadadi)

The University of Alabama
Nanoparticles Separation and Reclamation

Auburn University

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

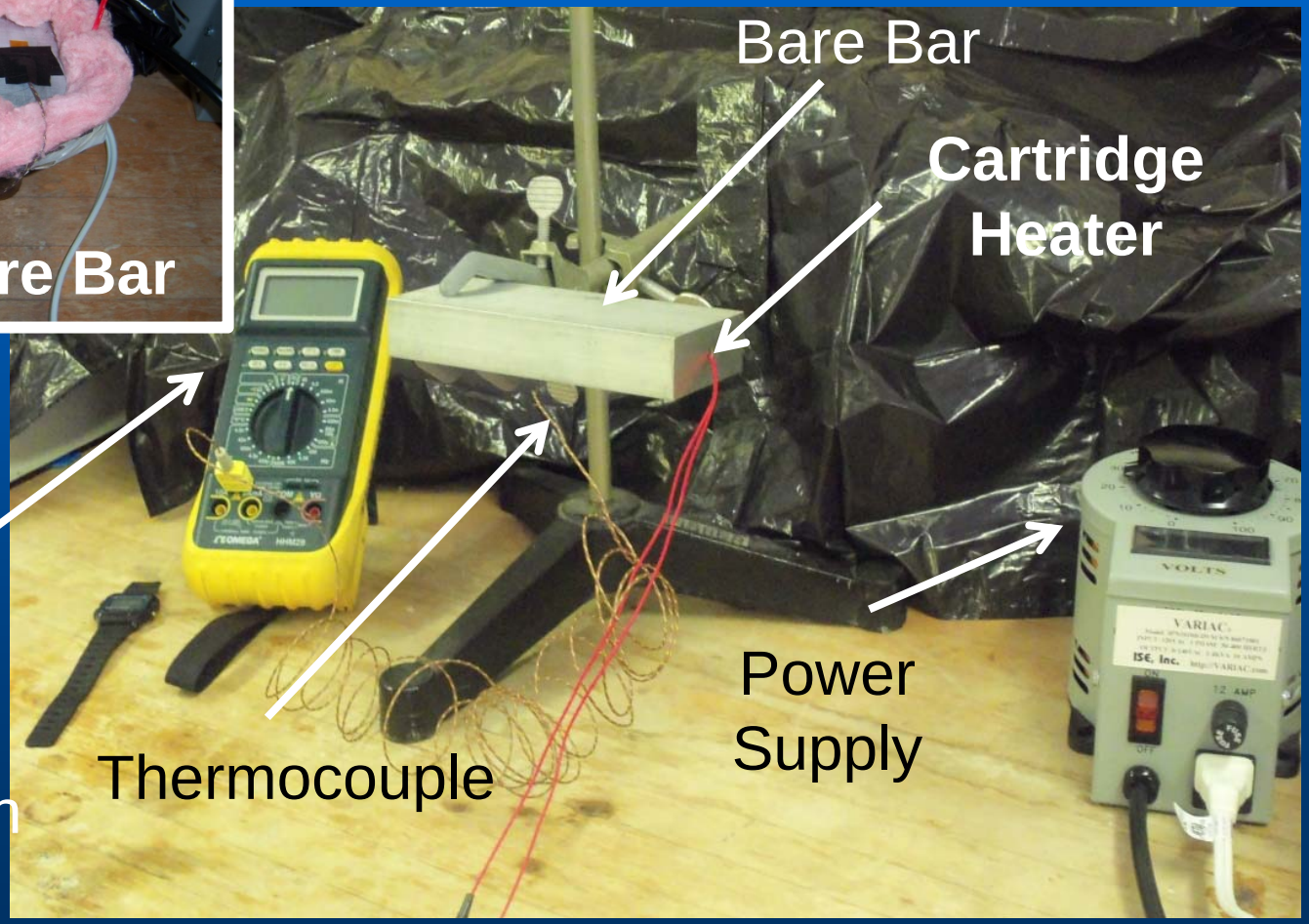


University of South Alabama
Thermal Conductivity and Heat Dispersion Effect

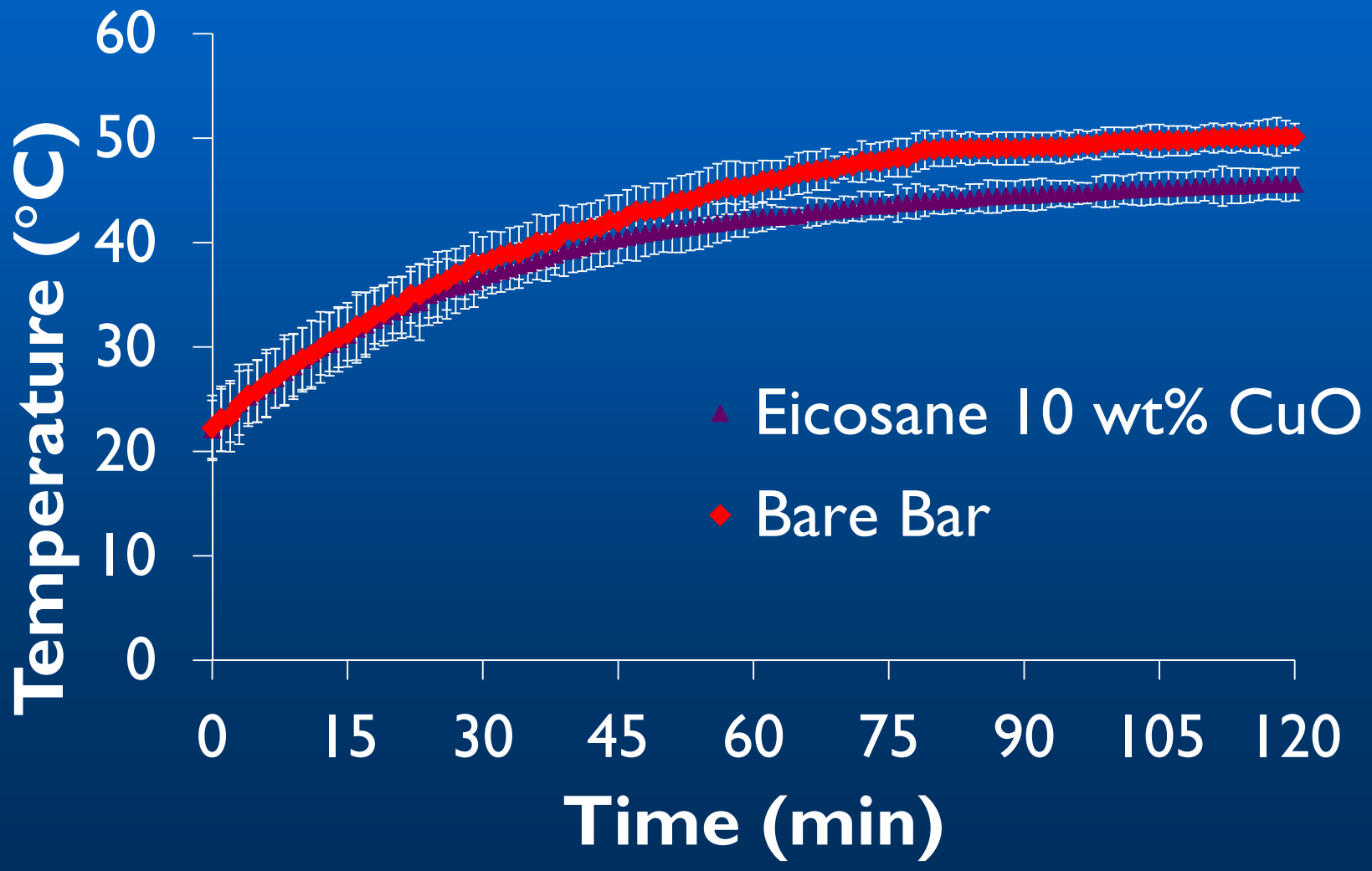
Tuskegee University
NEPCM in Package Level Micro Electronics Cooling

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

Experimental Station



Sample Experimental Data



Summary and Outlook

Method	ΔT (°C)	Power (W)	Space	Noise
Fin Array	5 ± 1	0	high	N/A
MCs	4 ± 3	<0.1	medium-high	varies
NEPCM	3 ± 1	0	low-medium	N/A
Fan	2 ± 1	0.9	medium	high

Going forward…

- ❑ Test other nanoparticles such as carbon nanotubes (k > 1000 W/m°C)
- ❑ Evaluate salt hydrate PCM
- ❑ Integrate microfluidics and NEPCM

Acknowledgements

- DOE EPSCoR for funding
- Prof. Jay Khodadadi for project leadership and overview slides
- Conference organizers

Questions?