

# BOSTON MATERIALS

Alternative to solder TIM 1 using liquid metal  
reinforced with Z-axis oriented carbon fiber

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# Boston Materials, Inc. – Company Overview

**New Class of Materials:** Advanced materials tailored for energy transfer.

**Z-axis Fiber Technology:** Proprietary roll-to-roll process aligns carbon fibers in the Z-axis direction (not nano-based), key to producing composites and films with high thermal, electrical, and structural energy transfer properties.

**Development History:** Over a decade of IP development, spun out from Northeastern University in 2016. Raised ~\$40M in funding.

**Applications:** Useful for creating electronics thermal management materials, lightweight aerospace composites, electrodes for energy storage, and more.

**Domestic Production:** Low-volume production in an ISO:9001-certified factory in Massachusetts; high-volume production build-out to be completed by Q2-2025.

**Leadership Team:** Led by Anvesh Gurijala (CEO, co-Founder) and executives from Intel, Henkel, and other key semiconductor suppliers.



# Emerging Thermal Challenges

**Dramatic increase in dimensions of die arrays – driving past 10X reticle on organic substrates**

**Local hot spots at edges : HBM and I/O at periphery**

**Extreme warpage driving increase in bond line thickness (BLT)**

TODAY

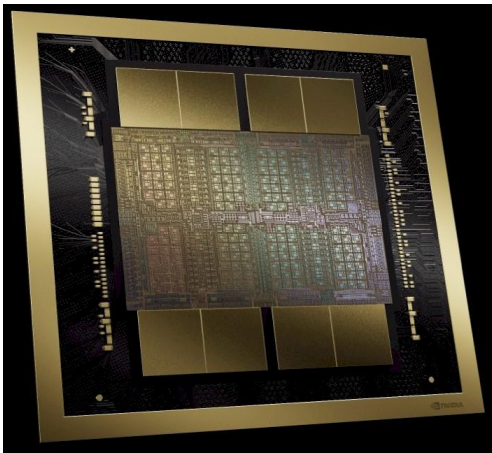
SOON



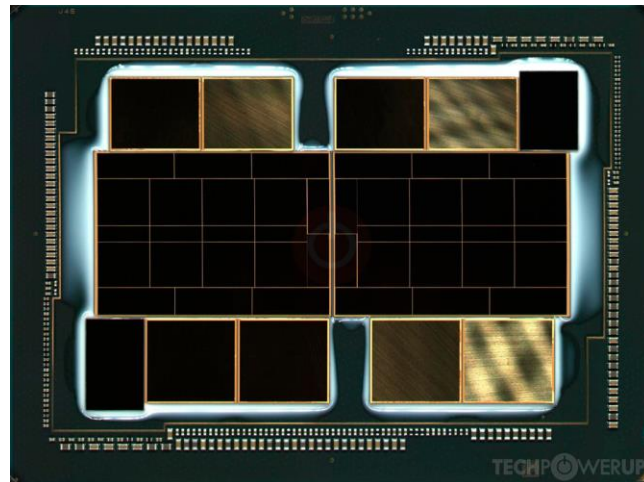
100s of Microns

Millimeters?

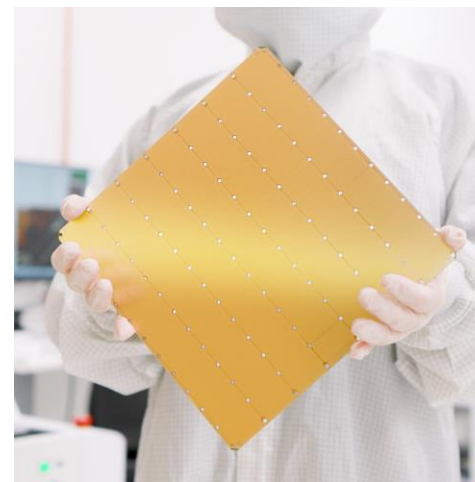
Not Science Fiction?



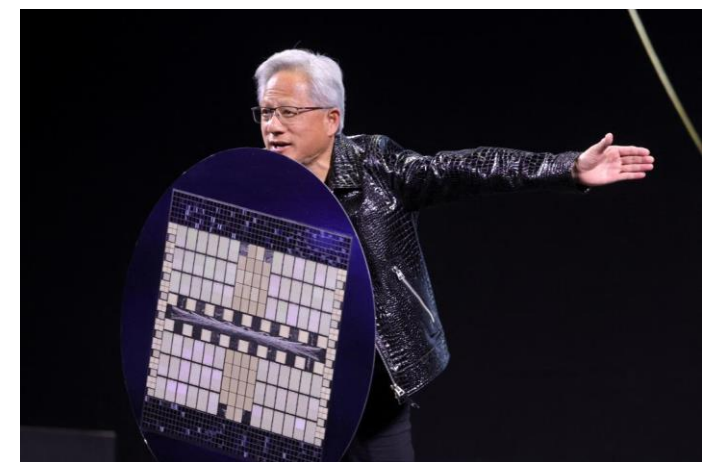
<https://www.nextplatform.com/wp-content/uploads/2024/03/nvidia-blackwell-die-shot-zoom.jpg>



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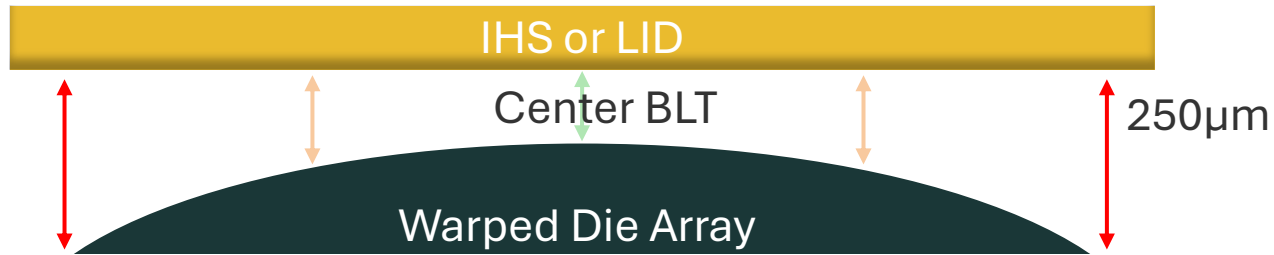


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# The Concept of Local Thermal Resistance



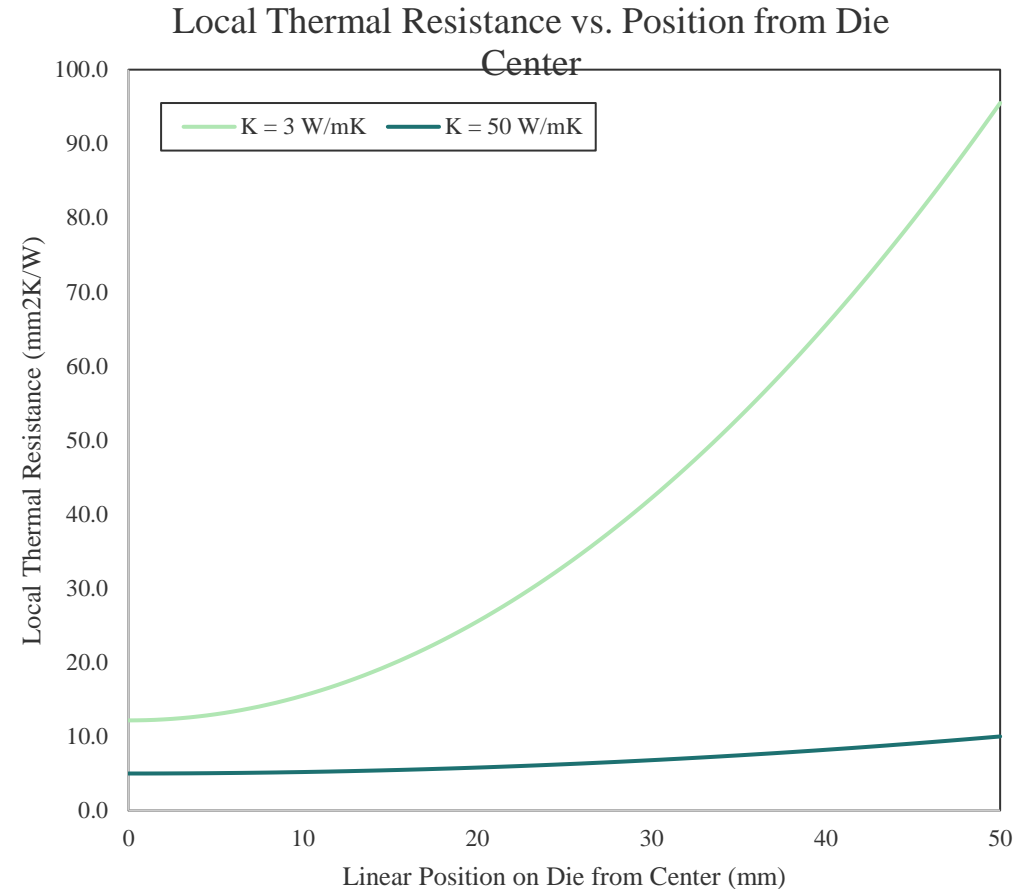
- Numerical model of theoretical 100 x 100 mm die array
- Assumed warpage from center crown to edge = 250µm
- Spherical cap shape assumed
- Interface resistance assumed = 3 mm<sup>2</sup>K/W
- Green Line = Grease TIM w/ center BLT = 35µm
- Dark Line = Metal TIM w/ center BLT = 100µm

**Bulk TC dominates with:**

**2X increase at 1X reticle**

**3X increase at 1X reticle + HBM**

**5X increase at ~4X reticle**



**High bulk thermal conductivity is critical for future trends: NEED METALS**

# Metallic TIM 1: Solid (Solder) vs. Liquid (LM)

Metals offer increased bulk thermal conductivity: Liquid Ga alloys  $>30$  W/mK , In Solder Alloys  $>60$  W/mK

**Thermomechanical stress issues reduced by operating as liquid, but at an expense!**

## Challenges / Barriers

### SOLDER TIMs

- Requires BSM
- Requires reflow + flux
- Requires liquid management during reflow
- High thermomechanical stresses in cycling
- No intrinsic BLT control

### DISPENSED LM

- Difficult to dispense and handle
- Requires mechanical surface wetting/application
- Requires complex dam/barrier solutions
- No intrinsic BLT control
- No intrinsic resistance to pumpout in cycling

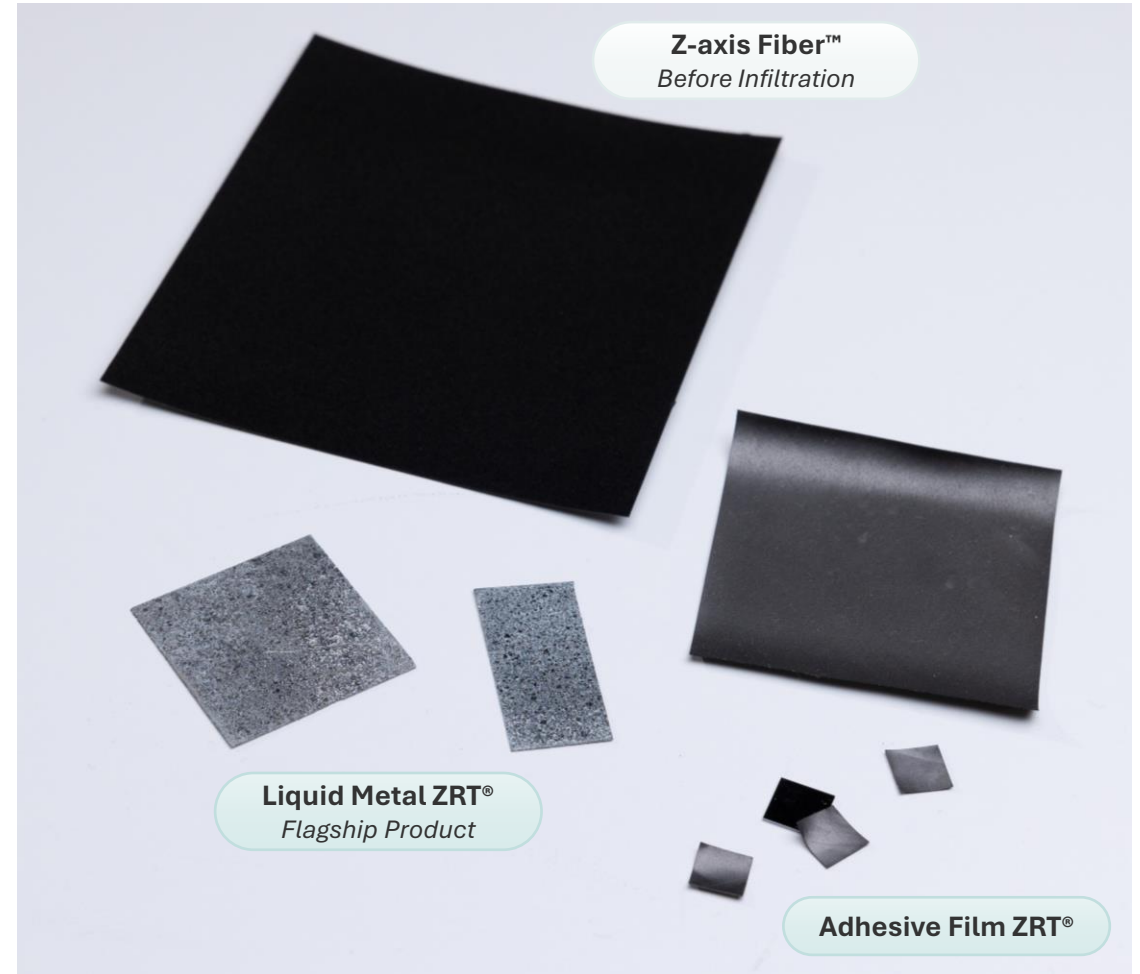
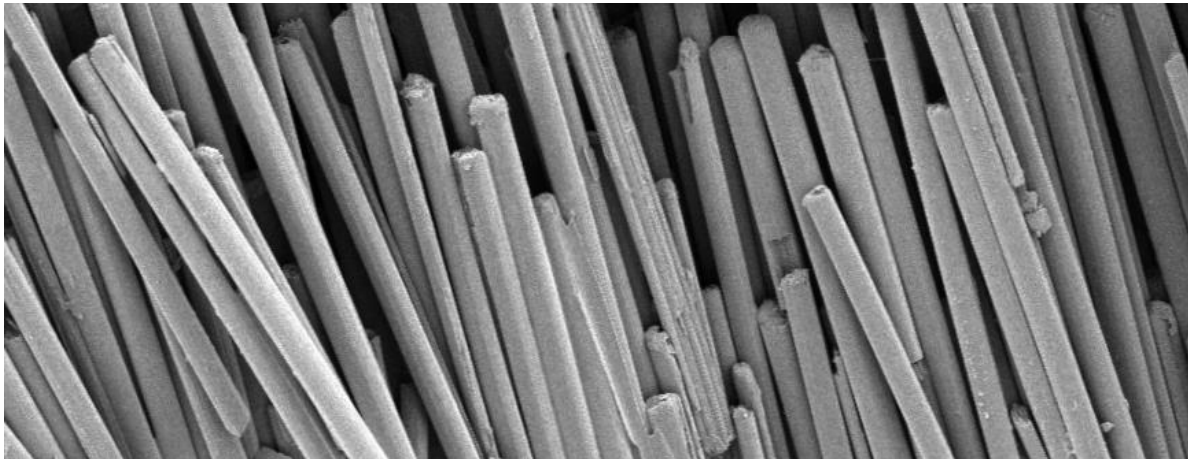
**Boston Materials LM-ZRT Composite Preform Removes Barriers to LM**

# Large Die Array TIM 1 Landscape

	Indium Solder Preform	Dispensed Filled Organic	Composite LM Preform (LMZRT)
Flux/Backside Metallization	X	✓	✓
Preform Format	✓	X	✓
Dependence on thin BLT	✓	X	✓
Voiding	X	✓	✓
Delamination	X	✓	✓
TC Pump-out	✓	X	✓
Cracking	X	✓	✓

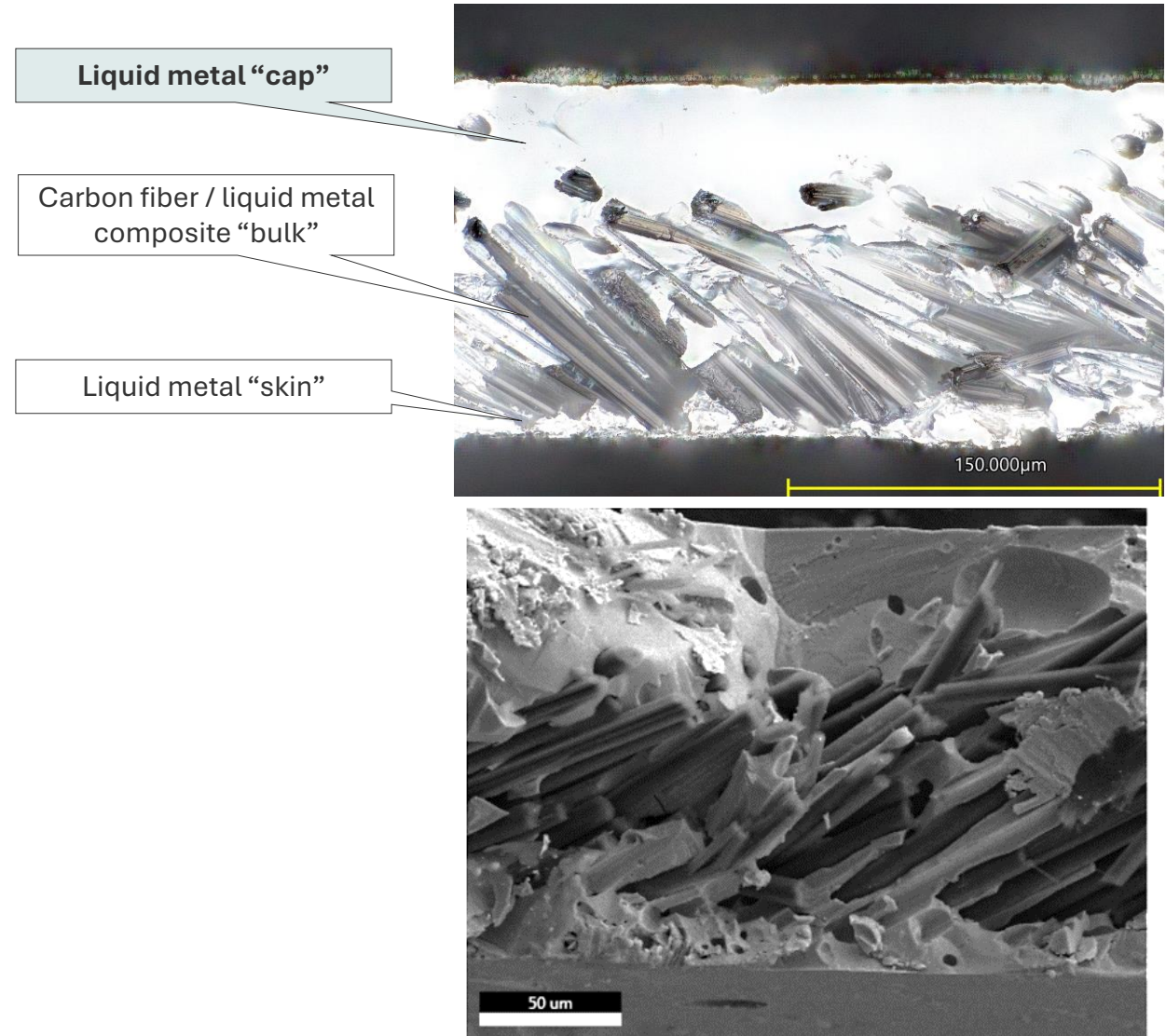
# Z-axis Fiber Technology

- Patented technology used to vertically align (Z-axis) carbon fiber using roll-to-roll process
- Z-axis aligned carbon fiber matrix is infiltrated with liquid metal alloy or adhesive film
- Not a nanomaterial; processing is highly automated



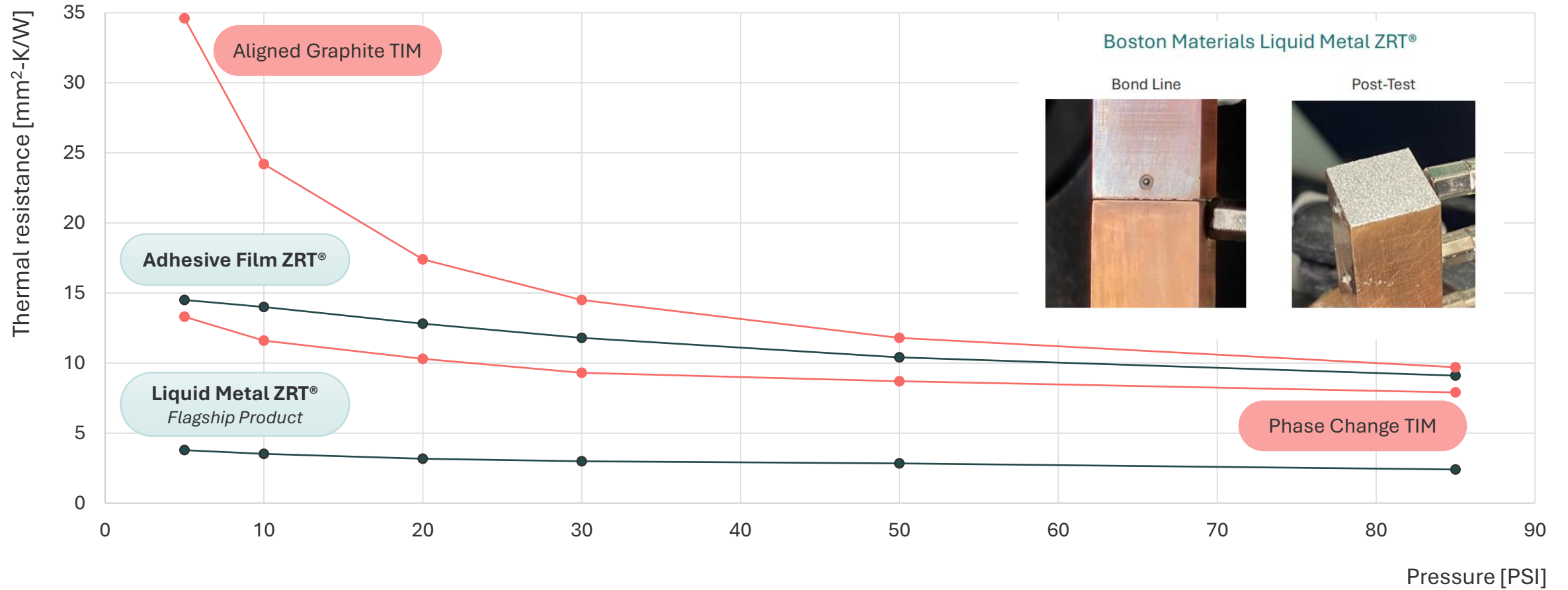
# Boston Materials Liquid Metal ZRT<sup>®</sup> (LMZRT)

- Composite of Pitch Carbon Fiber (900 W/mK) + Gallium Alloy (30 W/mK)
- Preform format with capability to 200 x 200 mm
- Handles solid, activates to liquid at ~30° C
- Interface wetting through local pressure at CF tips
- CF maintains BLT during lid attach process
- NO BSM, NO FLUX
- Effective TC (Interfaces Included) = 45 W/mK
- “Compressibility” = 25% at 30 PSI
- LM cap redistributes to accommodate warpage



# Nanotest TIMA 5 Thermal Resistance

ASTM D5470 Style Thermal Resistance



# TIM 1 Reliability Considerations for Metals

**High Temperature Storage**  
(150 °C, 1000 hrs)

- IMC Formation
- Void Maturation



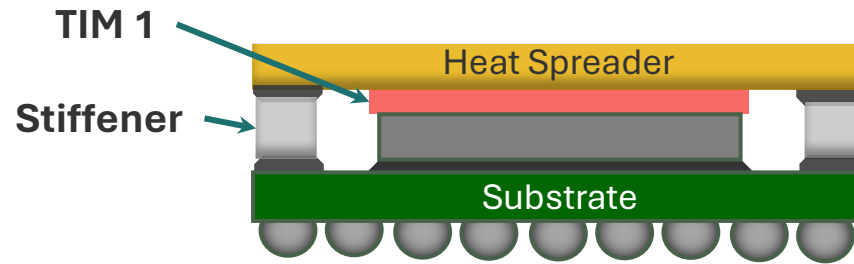
**SOLID vs. LIQUID**  
SOLID and LIQUID

**uHAST (130 °C, 85% Rh, 96 hrs)**

- Corrosion
- Foaming

In Progress

Presented Here



**Temperature Cycle B**  
(-55° C to 125° C, 1000 cycles)

- Delamination
- Fracture
- Pumpout

In Progress

**Solder Reflow (245 °C, 3x)**

- Void Expansion
- Delamination



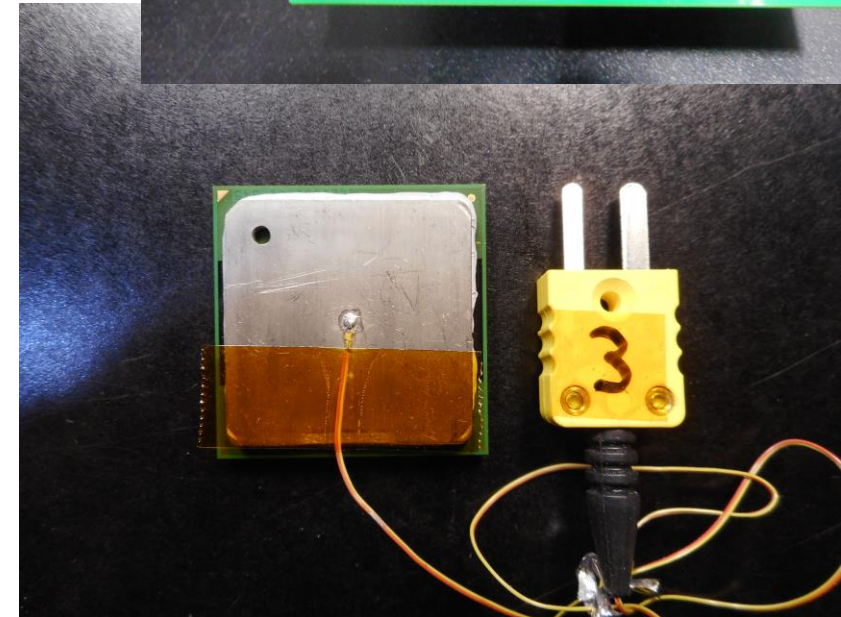
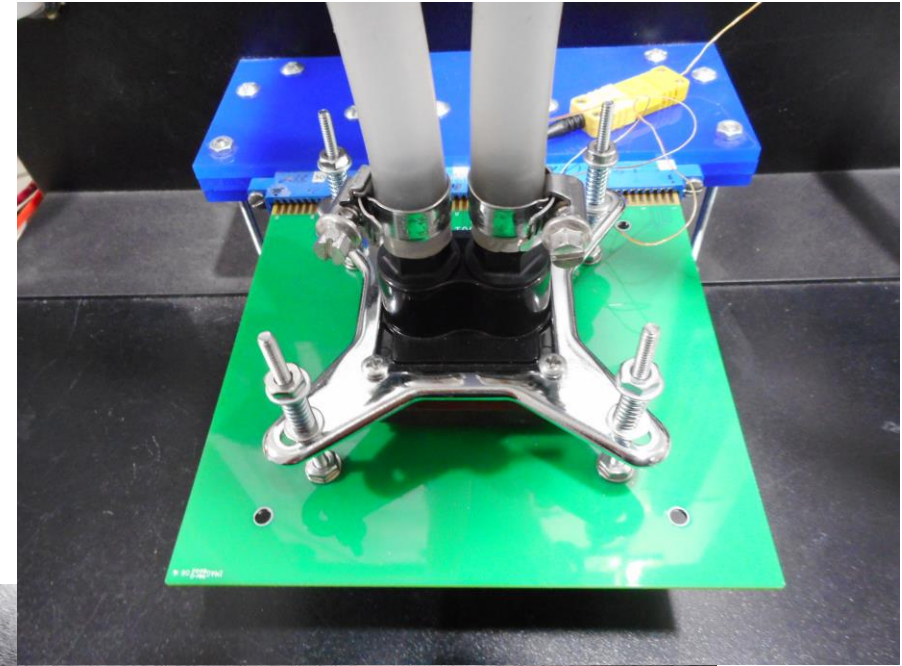
# Temp Cycle TTV Overview

## Organic Substrate

### Failure Modes Investigated:

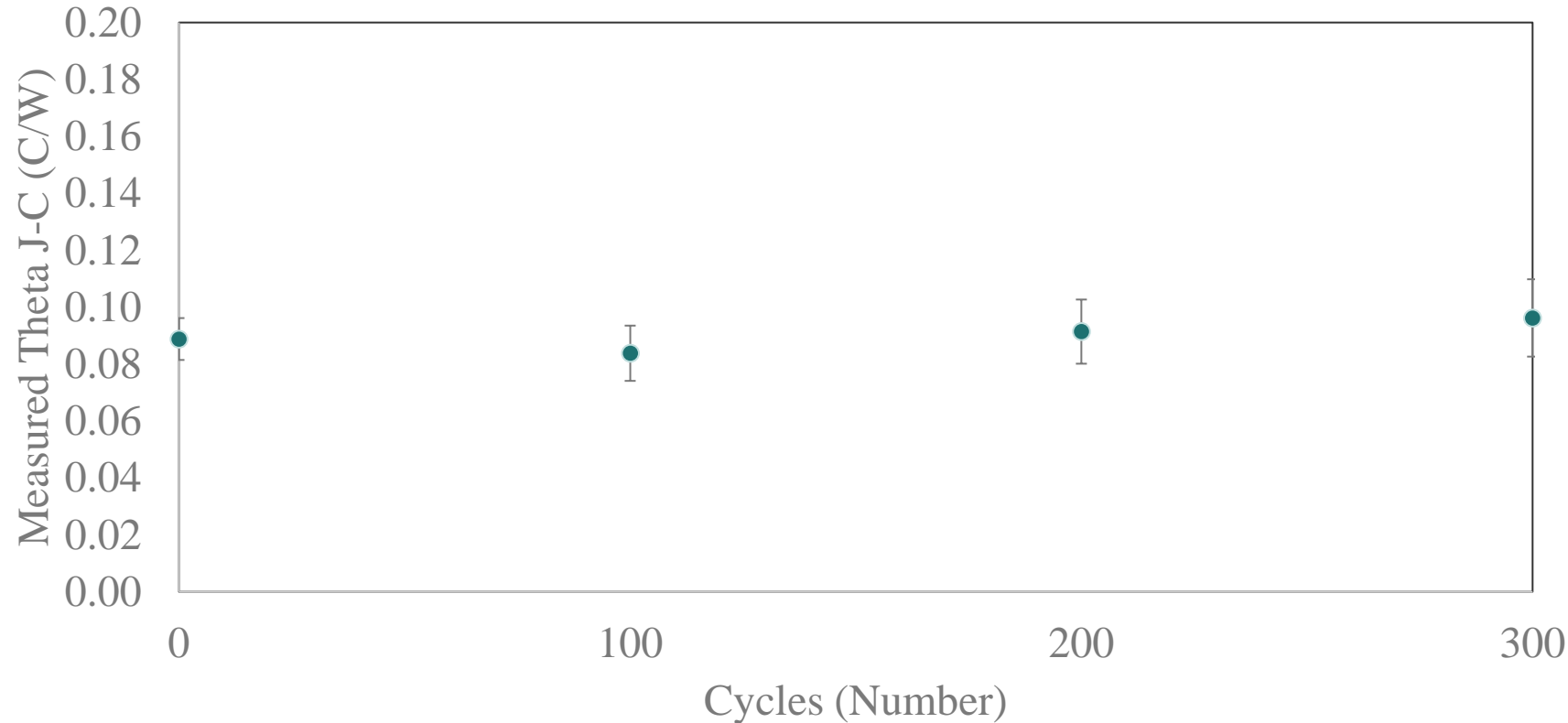
Dispensed LM = No resistance to pump-out  
Solder TIM = Thermomechanical stress breakdown

- Test Conditions:
  - Preconditioning (MSL4) and 3X Reflow (245° C) prior to Time 0
  - TCb (-55° to 125 ° C), 1000 cycles (measuring every 100, 300 complete)
  - Standard formulation LMZRT tested, with no encapsulation
- TTV Details:
  - Package Type: FC-PPGA
  - Substrate Dimensions: 35x35x1.22mm
  - Die Size: 11x13mm
  - Lid Size / Thickness: 31x31x1.5mm
  - Lid Attach Material: DOWSIL SE 4450
  - Lid Attach Conditions: 90 min 125° C 30 PSI



# Temperature Cycle B ( $-55^{\circ}\text{C}$ to $125^{\circ}\text{C}$ )

## Temperature Cycle B Theta J-C vs. Cycles



### Notes:

- Pumpout would result in large Theta J-C increase
- No **significant increase** in Theta J-C indicates stability of LMZRT

### Next Steps:

- 3/10: 1000 Cycles results

**Initial Stability Through 300 Cycles**

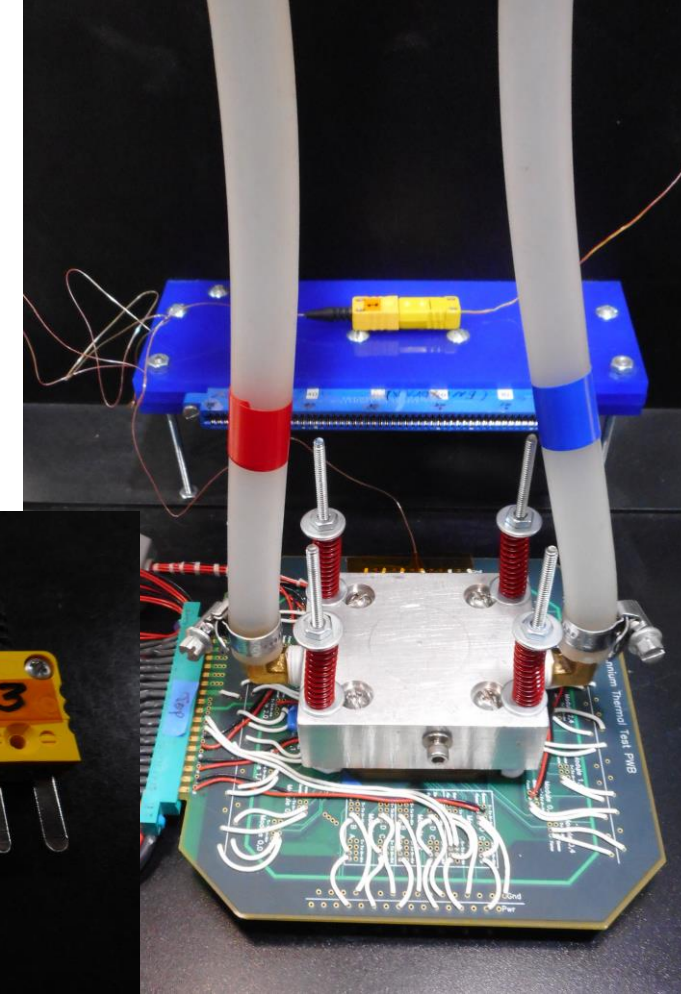
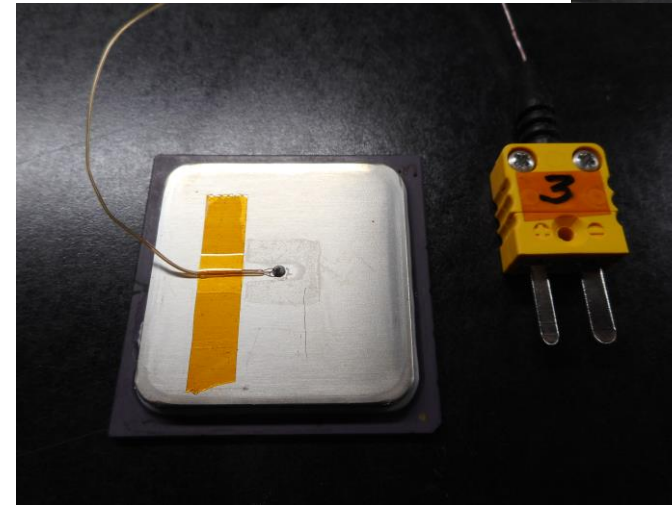
# High Temperature Storage TTV Overview

## Ceramic Substrate

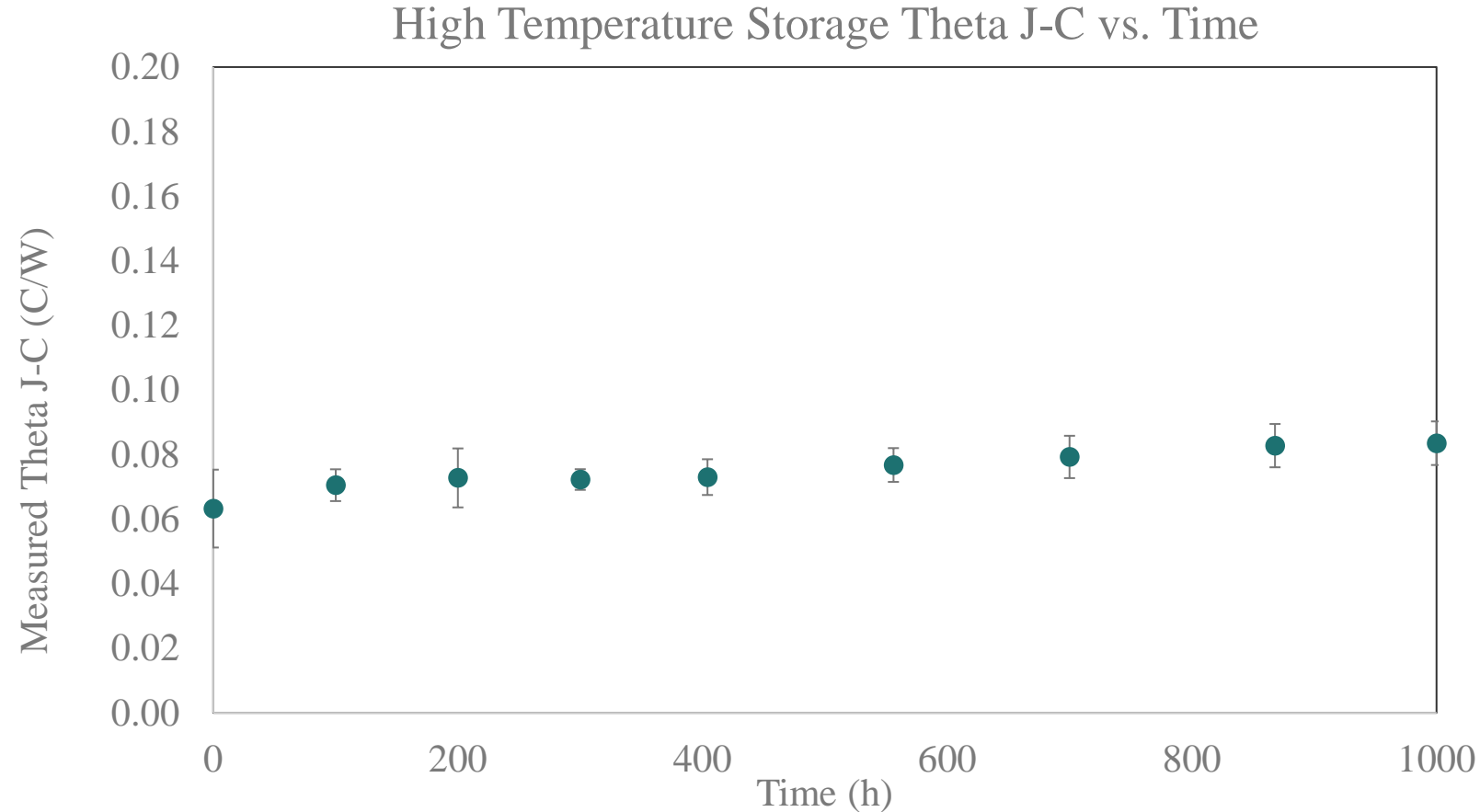
### Failure Modes Investigated:

Void Maturation  
IMC Maturation  
Material Breakdown

- Test Conditions:
  - Preconditioning (MSL4) and 3X Reflow (245° C) prior to Time 0
  - 150° C, 1000 hours
  - Standard formulation LMZRT tested
- TTV Details:
  - Package Type: Ceramic LGA
  - Substrate Dimensions: 45x45x1.5mm
  - Die Size: 13x13mm
  - Lid Size / Thickness: 37.5x37.5x2.4mm
  - Lid Attach Material: DOWSIL SE4450
  - Lid Attach Conditions: 90 min 125° C 30 PSI



# High Temperature Storage (150° C – 1000 hours)



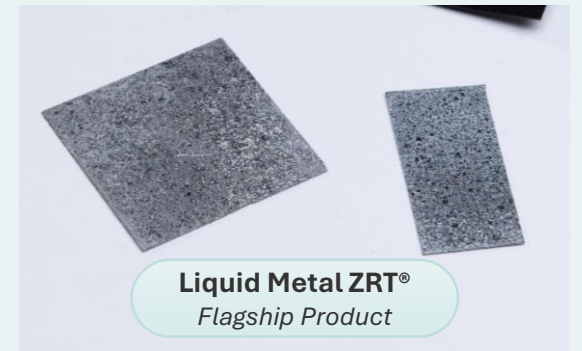
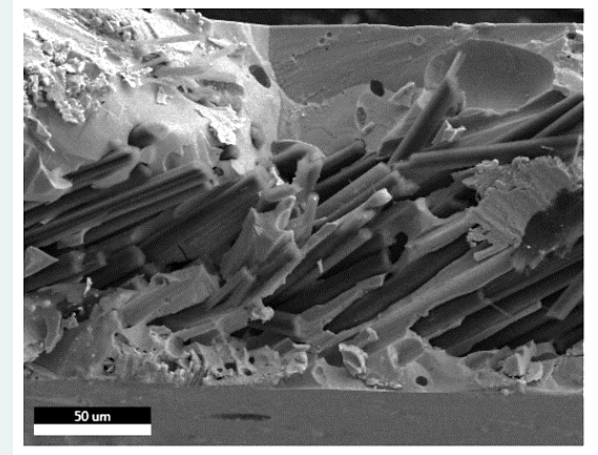
## Notes:

- Available organic flip chip TTV was not rated for 150°C operation
- 0.064 C/W measured at T0
- 0.084 C/W measured at T1000
- Next Steps: Delidding and characterization using SEM and EDS

**Low thermal resistance maintained through 1000 hours**

# Summary and Contact

- As die array sizes increase, **warp** and BLT increase
- Existing solutions cannot meet the thermal and processing needs of expanding packages
- Boston Materials' LMZRT preforms eliminates barriers to using liquid metals in TIM 1 applications
- LMZRT: low interface resistance, redistribution to accommodate warp, stability and processability of a solid preform, integrating into solder TIM workflows
- LMZRT demonstrates stability in MSL 3 + 3X reflow (245° C), HTS (150° C for 1000 hours), and preliminary TC (Condition B: -55° C to 125° C through 1000 cycles)
- LMZRT is currently available in dimensions to 150 mm x 150 mm with up to 250 mm x 250 mm targeted for mid '25.



**Questions please contact:**  
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