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Modern Materials for a Connected Society

Liquid Metal Embedded Elastomers as High-performance S-TIM Replacements

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3-14-2023

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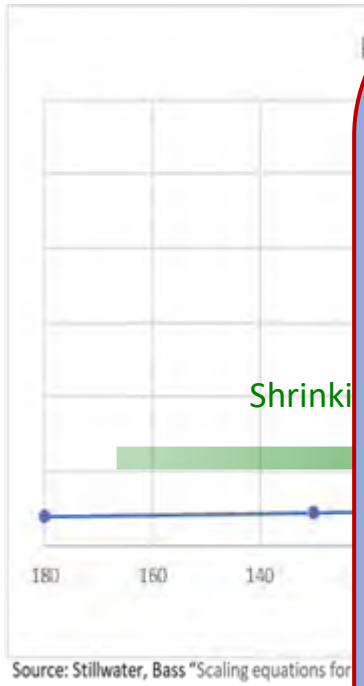
Speaker Introduction

Dr. Keyton Feller

- Bachelor of Science, Chemistry
  - University of Wisconsin Platteville, 2017
- PhD, Macromolecular Science and Engineering
  - Virginia Tech, 2023
- Polymer Chemist
  - Arieca, 2022-Present

Motivation

Moore's Law **Meets** **Physically Constrained Footprints**



Source: Stillwater, Bass "Scaling equations for

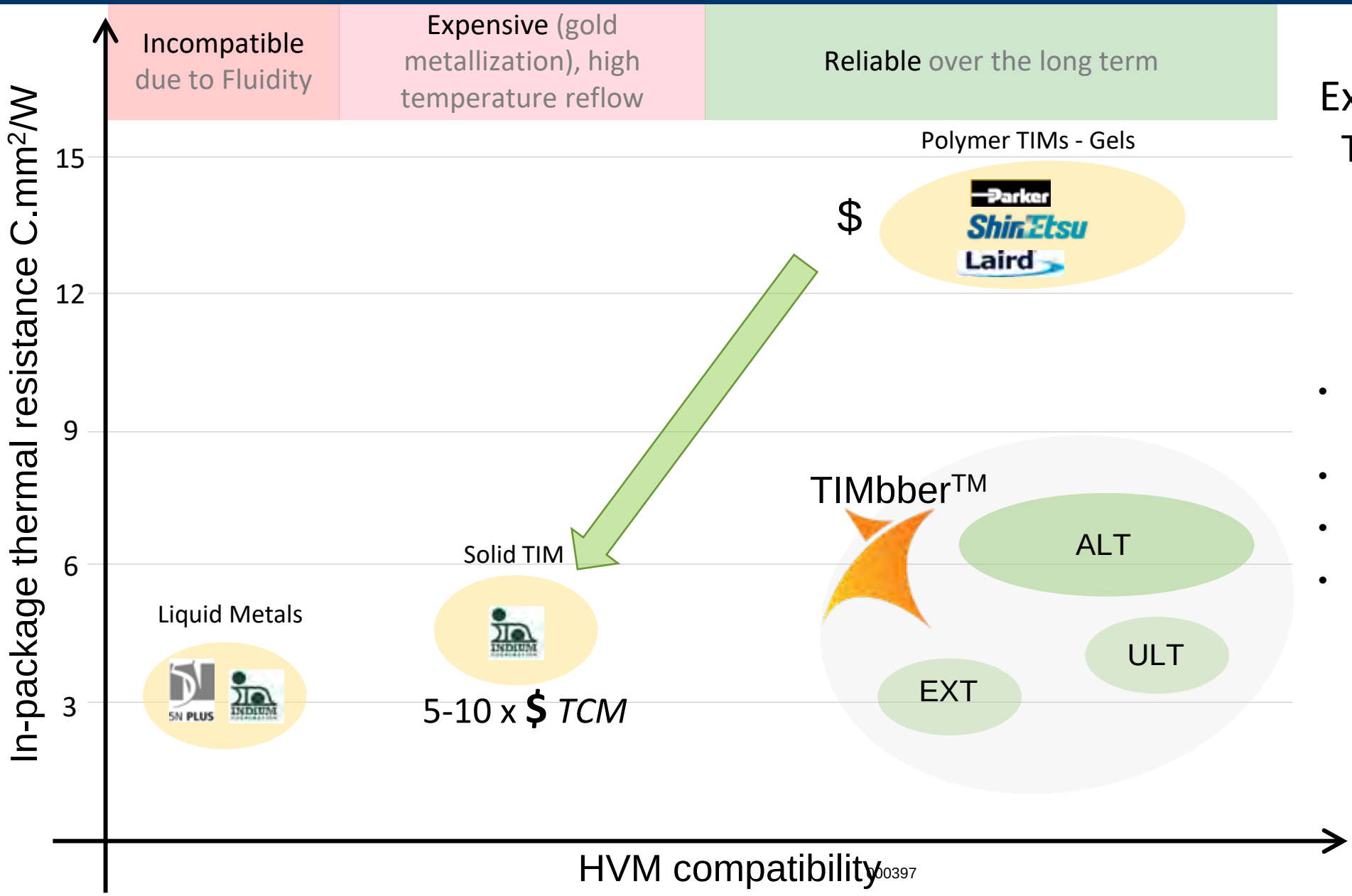
Expand More

TDP >> 100
high pe

Objective: To Develop Thermal Interface Materials (TIM1) with

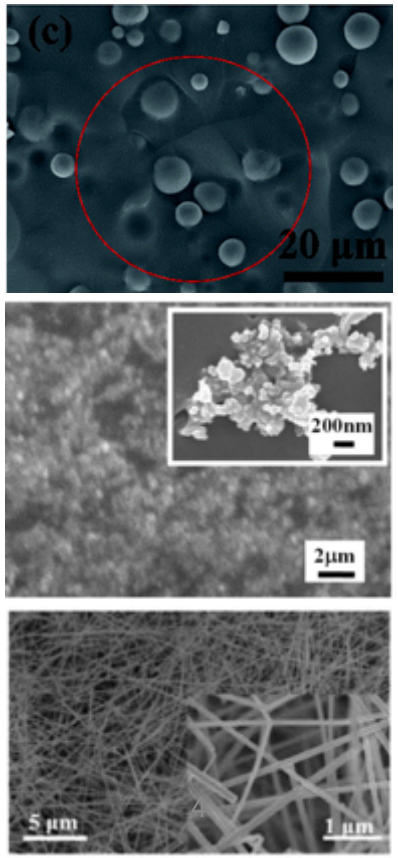
- Thermal Resistance approaching of Liquid Metals
- Mechanical Reliability Performance of Polymer-TIMs
- Ease of Semiconductor Packaging Manufacturing of Greases

Existing Solutions - Thermal Interface Materials (TIMs)



The tradeoff:
Existing high-performance TIMs are not compatible with HVM

- Aluminum Oxide
- Silver
- BN
- Vertically aligned Carbon



Properties of liquid metal

Indium Corp.
5N plus

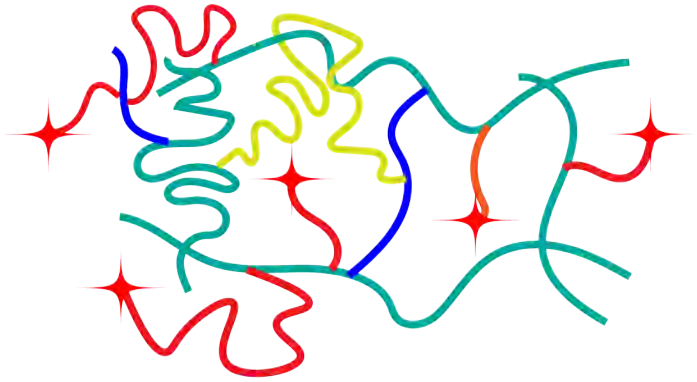
Chiechi et al., Angew. Chemie - Int. Ed. 2008

Joshipura et al., J. Mater. Chem. C., 2015.

- Eutectic Gallium Indium (74.5% Ga, 24.5% In; by weight)
- Low melting point ~ 15.5°C
- Negligible toxicity
- Low viscosity 1.99 cP
- High electrical and thermal conductivity ($\sigma = 3.4\times10^6$ S/m, k = 26.4 W/m·K, at ~30°C)

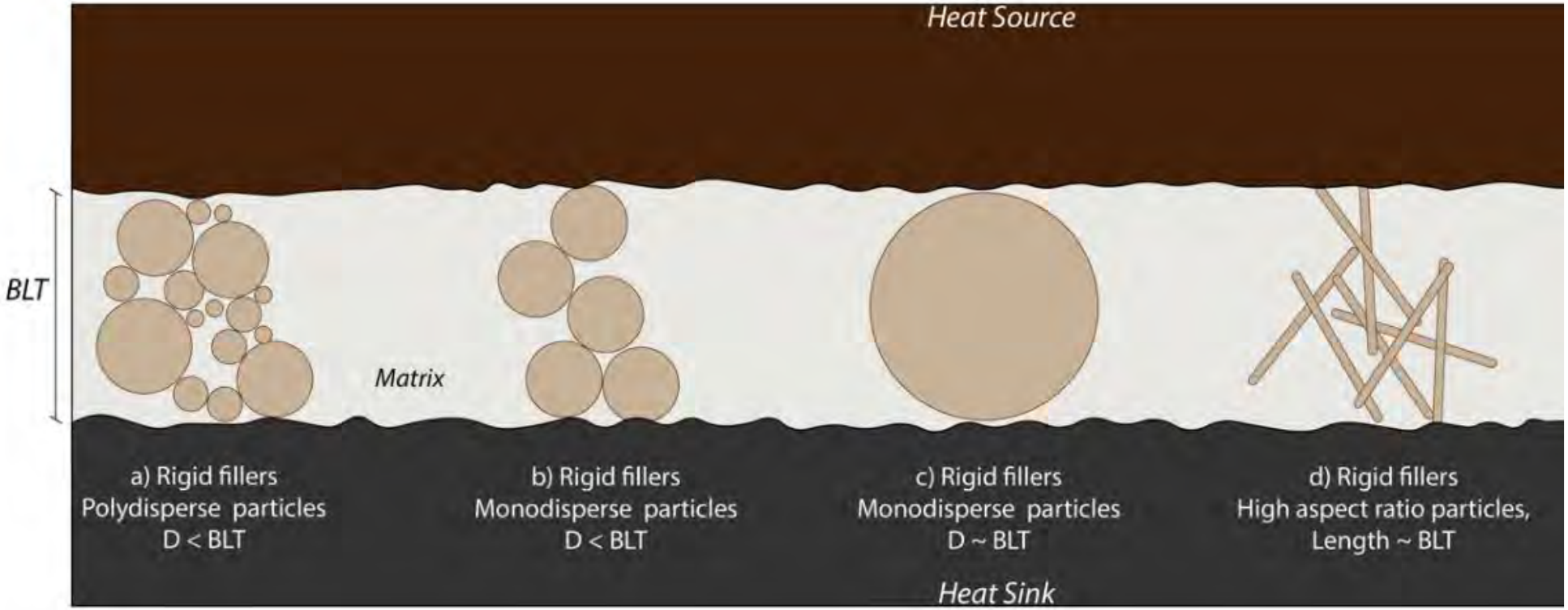
Composition and Development Liquid Metal Embedded Elastomer (LMEE)

Optimized Polymer Formulation



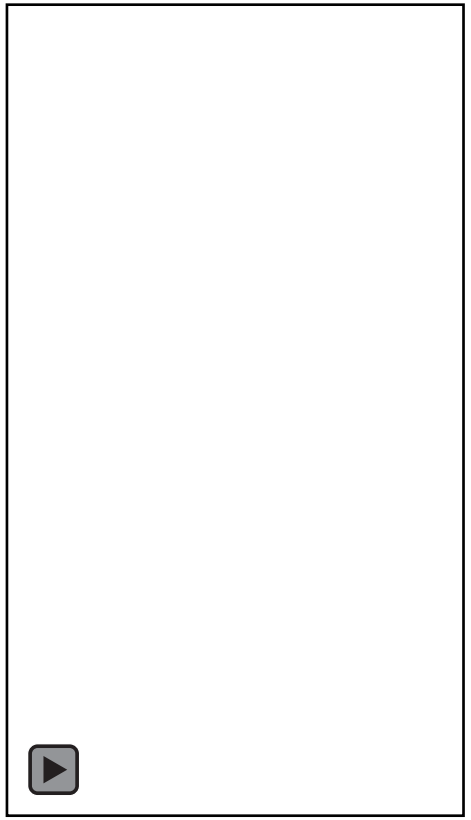
- Provides structure to support liquid metal droplets
- Enables adhesion and high elongation
- Allow crosslinking to form high reliability elastic solid

Why use LMEE?



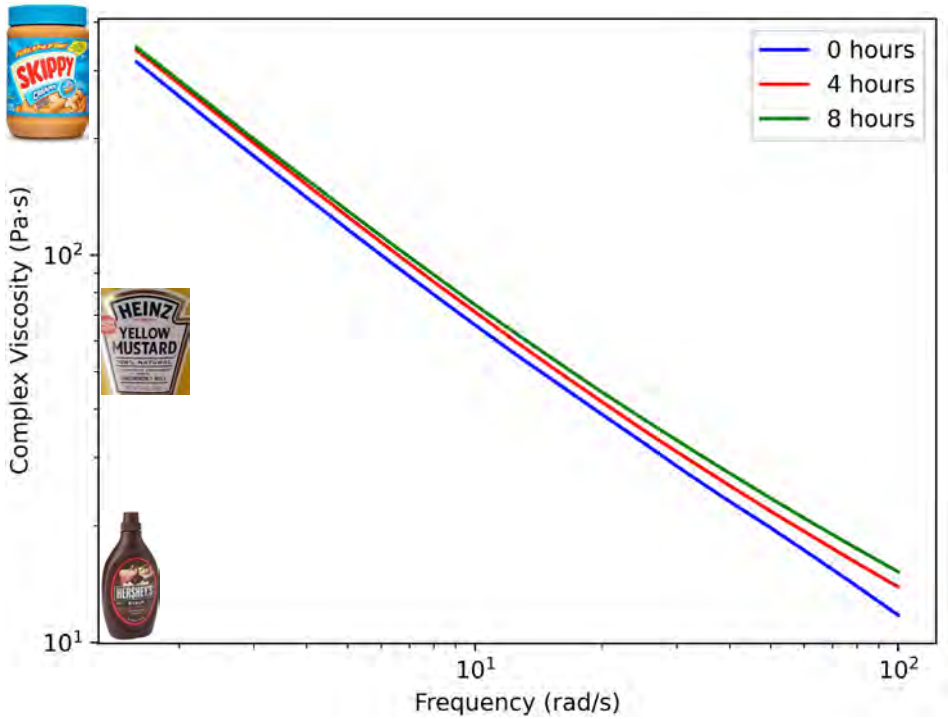
- All other polymer TIMs microstructures (a-c) have high contact resistance between particles, as well as between particles and interfaces. Particle Size < BLT
- Arieca's Liquid Metal TIM provides extremely low thermal resistances by compressing liquid metal particles at low BLT. Particle Size > BLT

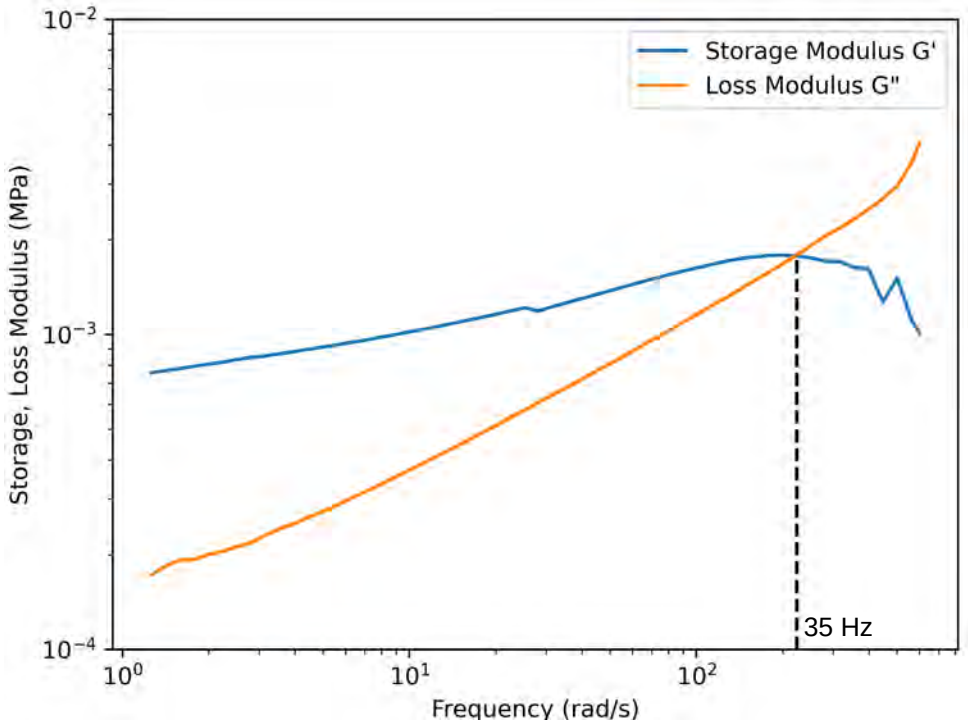
Droplet size analysis of LMEE



Encapsulated liquid metal droplets have diameter between 100-150 µm

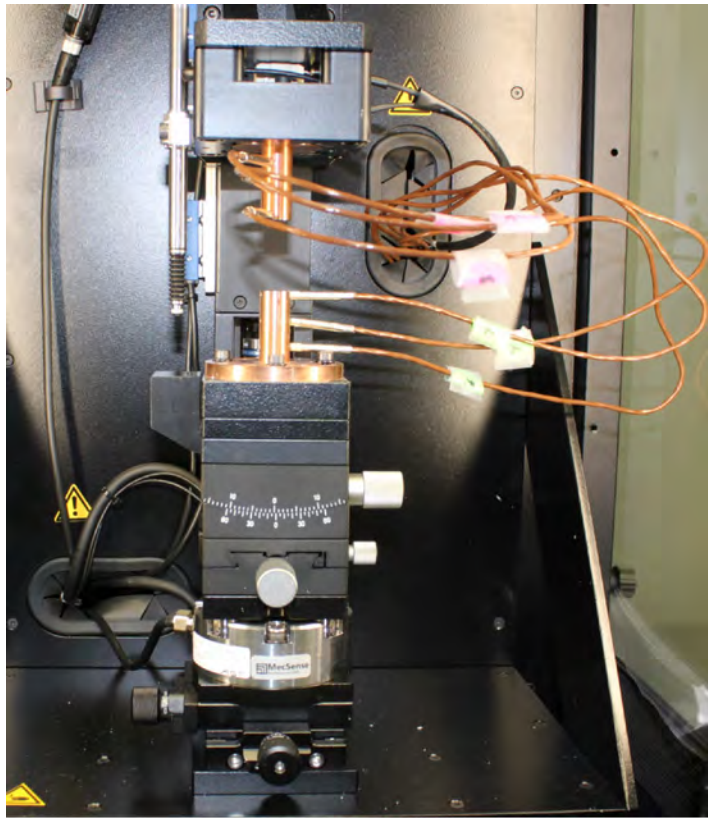
Rheological properties of LMEE

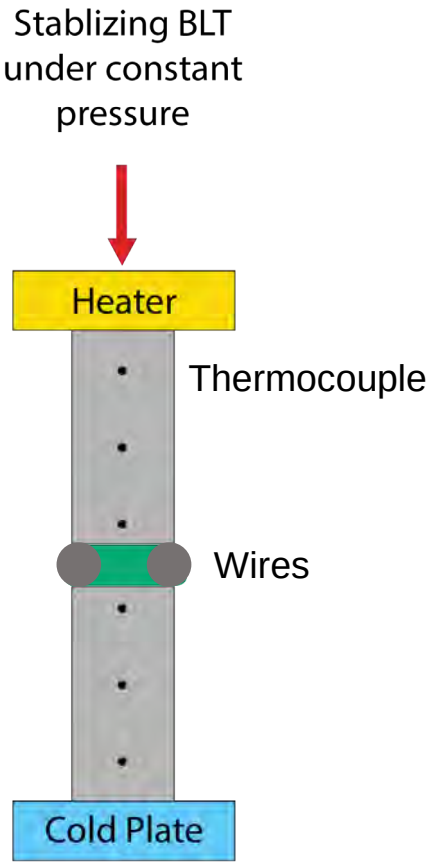


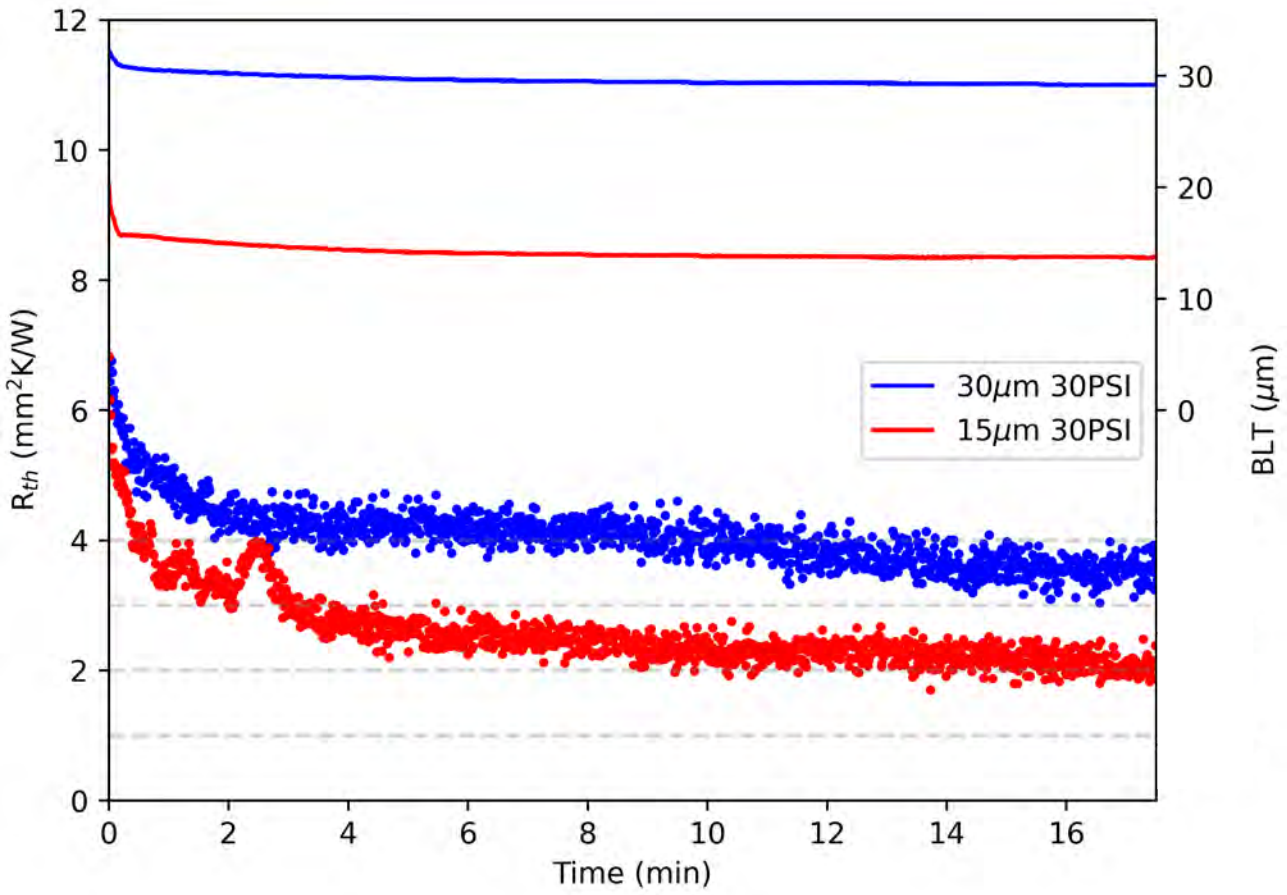


LMEE exhibits long working time and low viscosity for ease of dispensing and patterning

Thermal Performance of LMEE

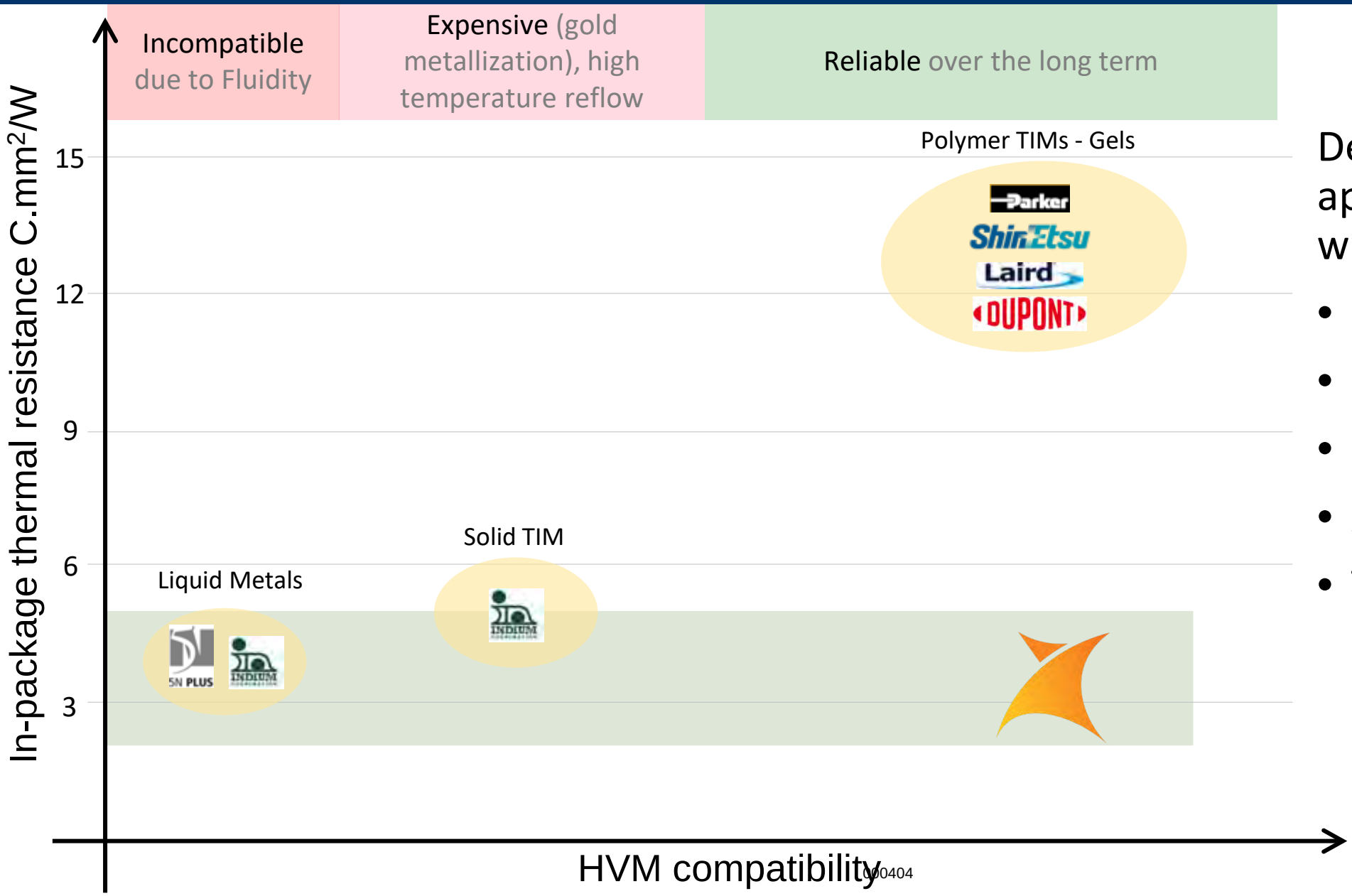






LMEE reaches low BLT and demonstrates comparable thermal performance to S-TIM

Existing Solutions - Thermal Interface Materials (TIM1)



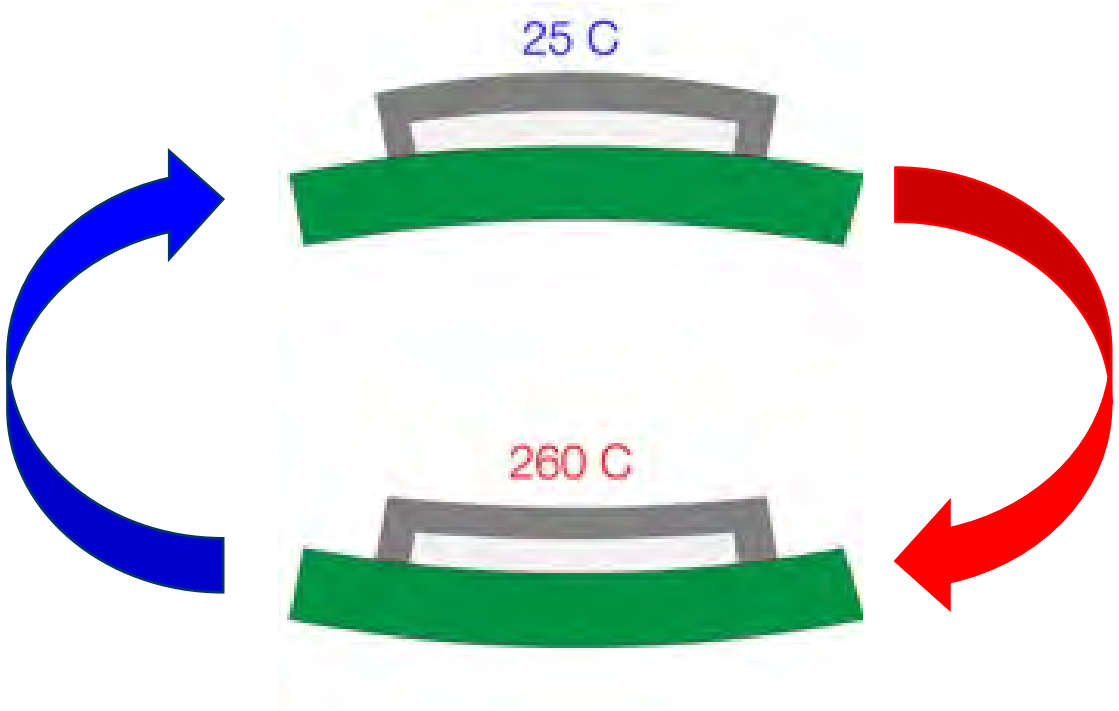
Designed to find application in packages with:

- Large die
- Latest node technology
- Server
- AI/ML
- Tensor processor.

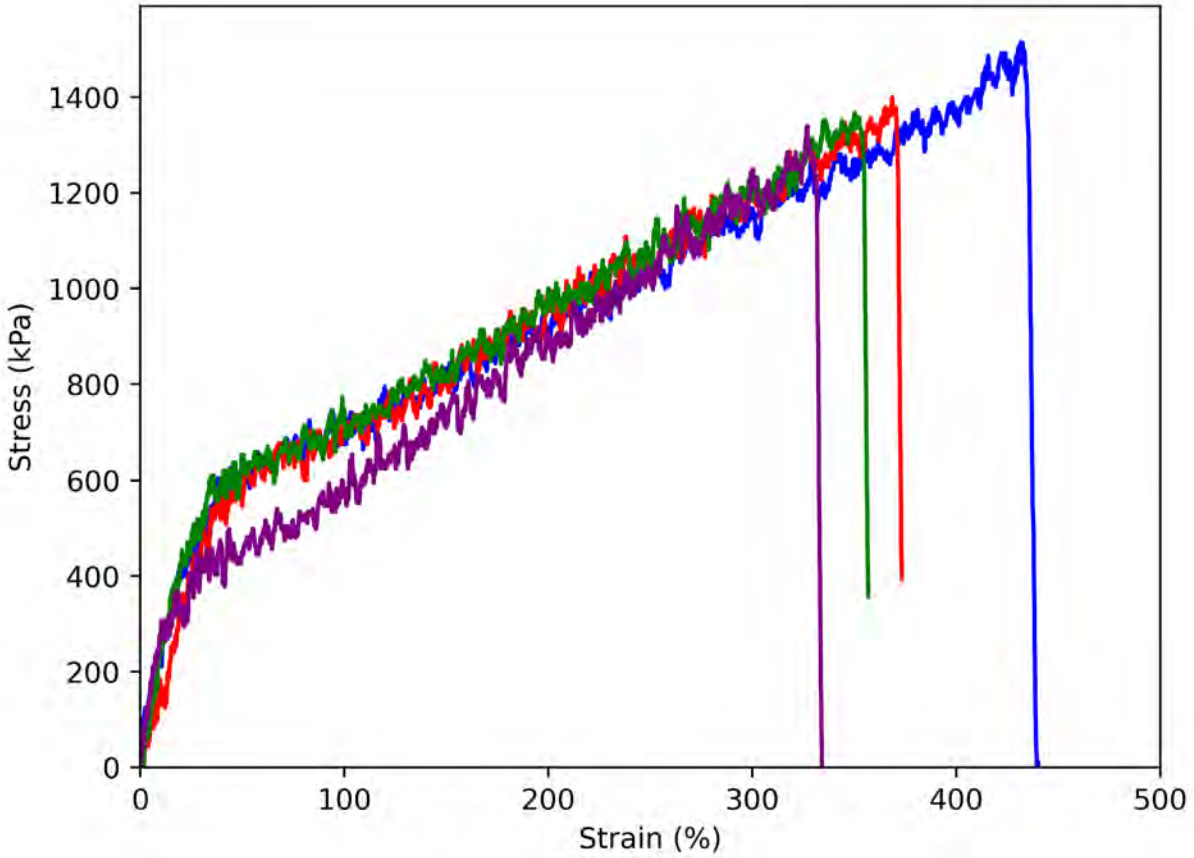
Reliability Requirements for TIMs

- TIMs must pass TST, UHSAT, BAKE to be viable in package

- Arieca engineers 3 key properties to aid in reliability
  - Stretchability
  - Adhesion
  - Thermal stability

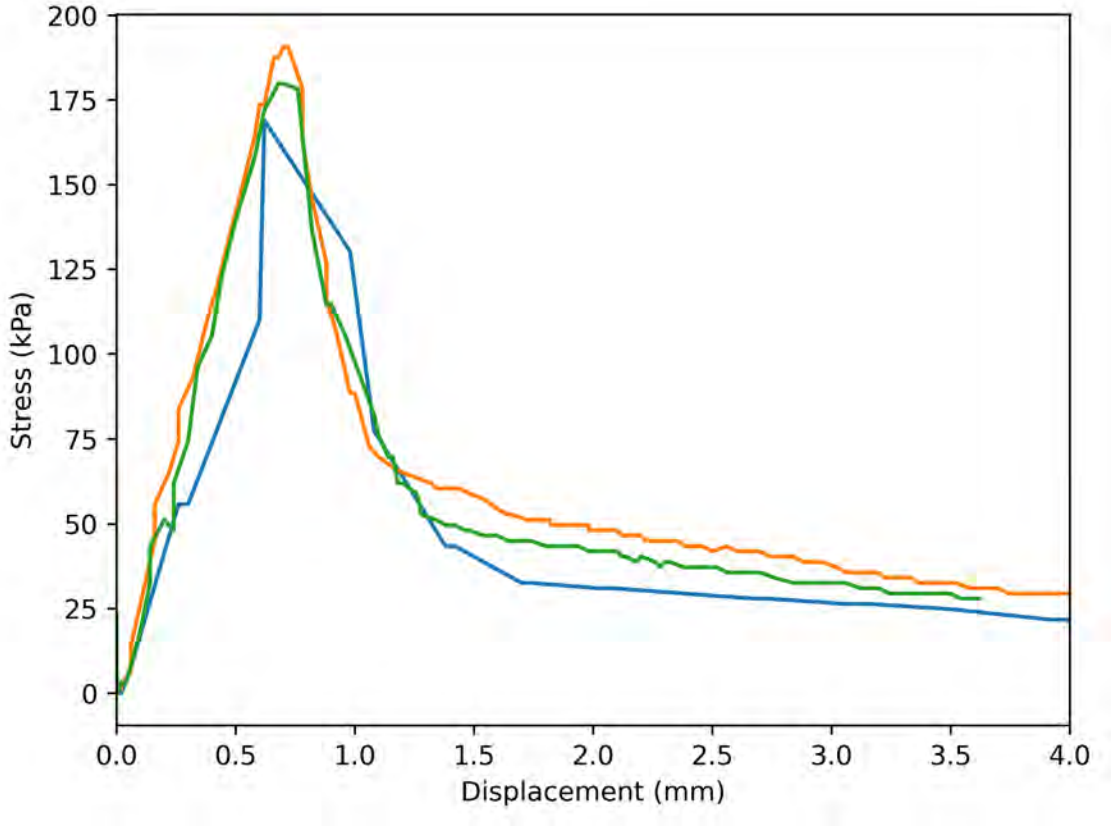


Mechanical Properties of LMEE



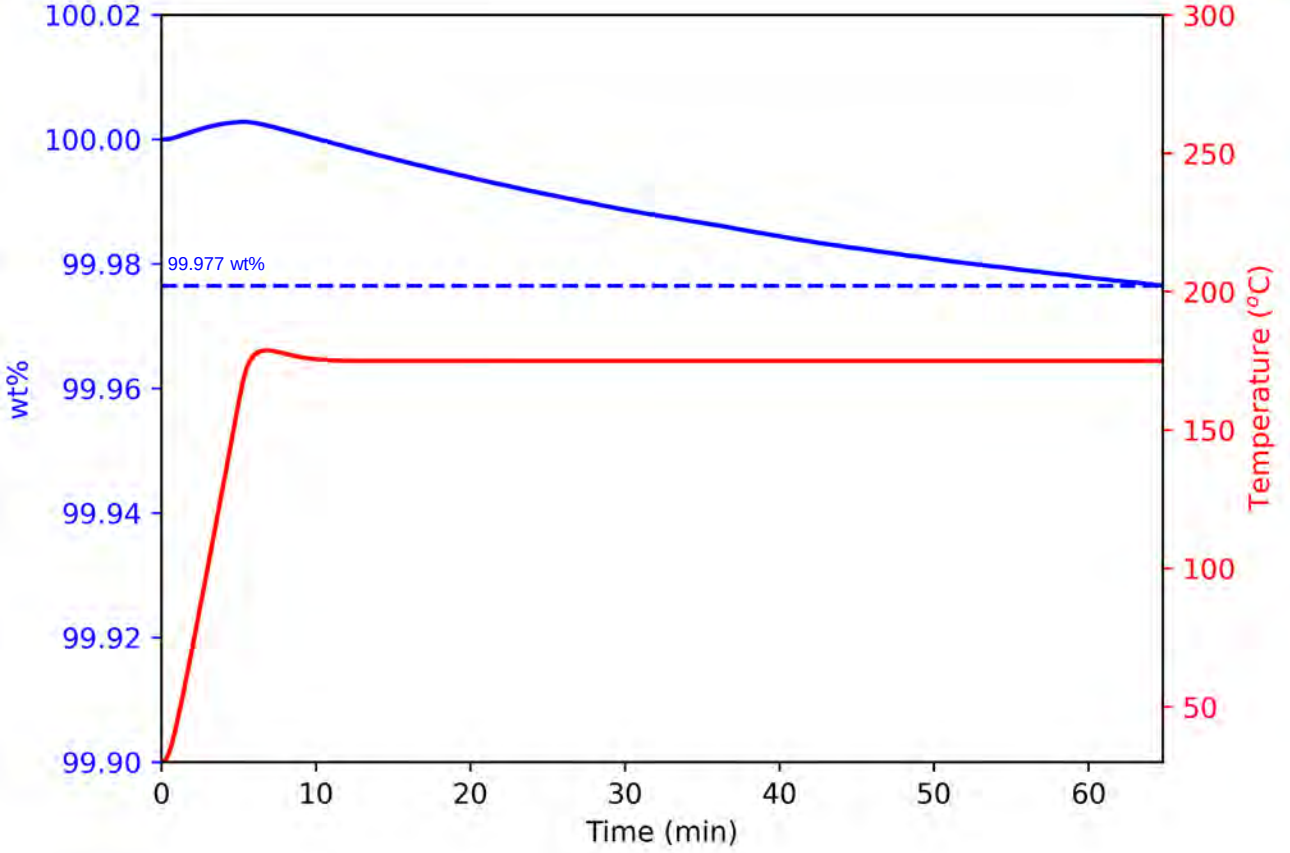
High elongation of LMEE allows for high reliability in package even at low BLT (<30 µm)

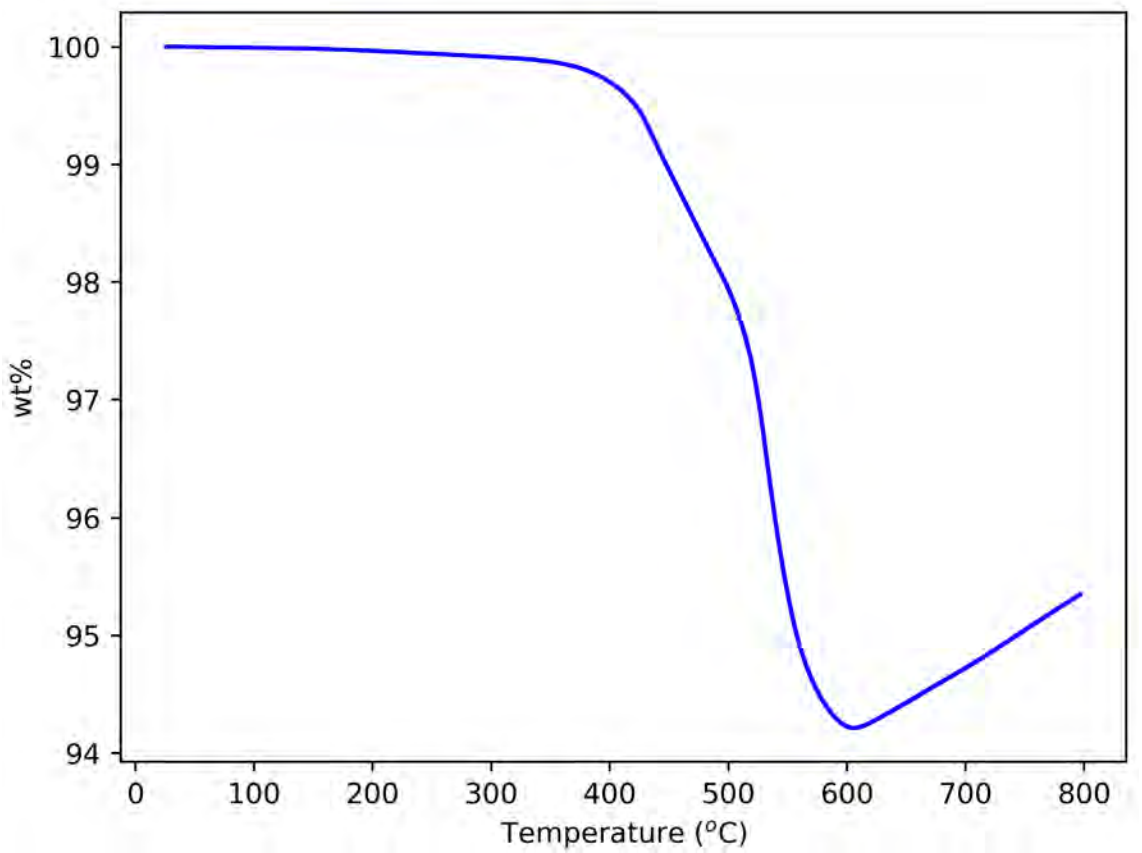
Adhesive properties of LMEE



LMEE exhibits high adhesion to nickel substrates and cohesive failure

Outgassing and thermal stability of LMEE





LMEE exhibits low outgassing (<0.03 wt%) and is thermally stable up to 400 °C

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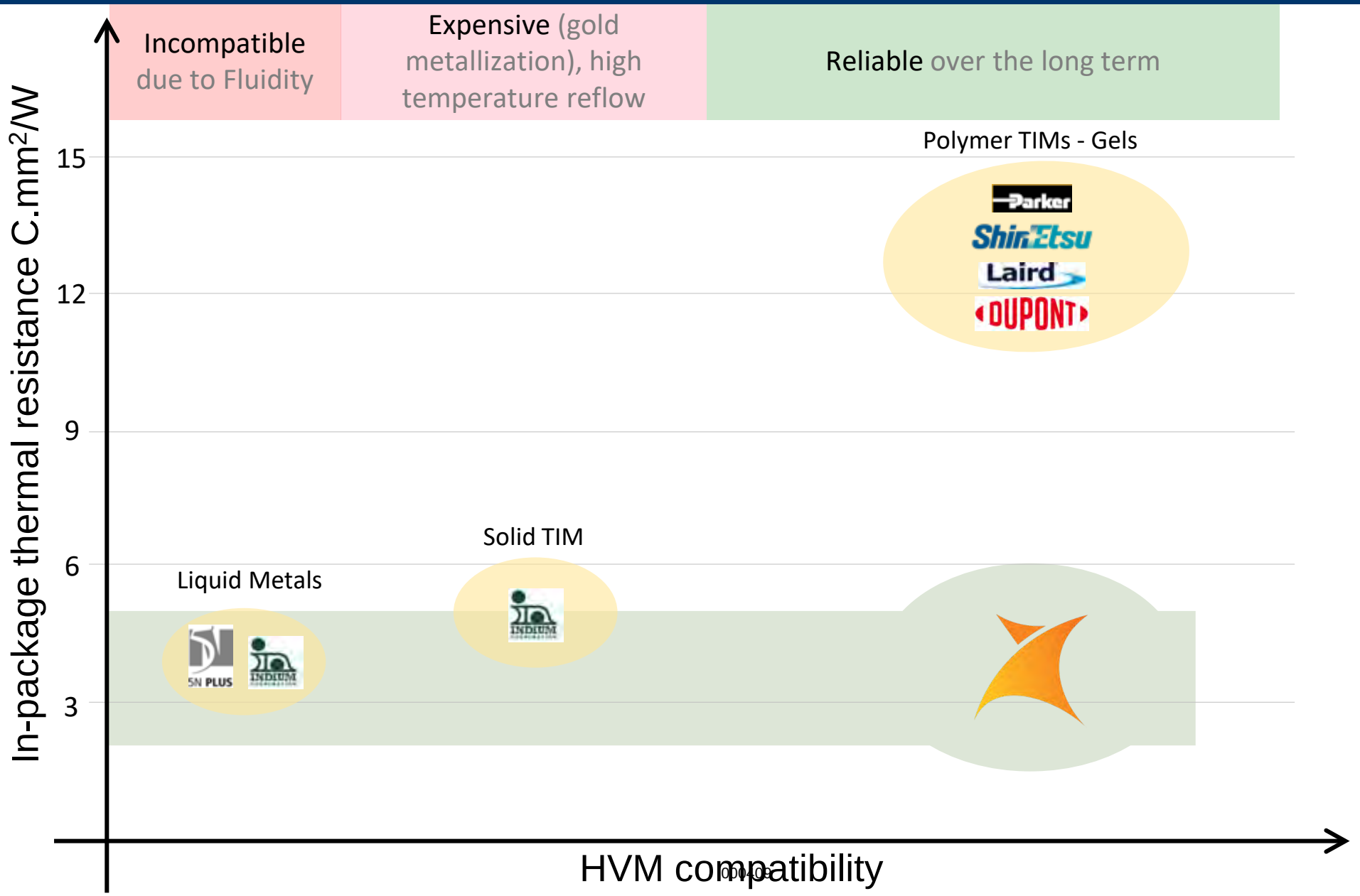
Existing Solutions - Thermal Interface Materials (TIM1)



Summary

- Demonstrated LMEE is easily processible and mechanically robust/reliable
  - <400 Pa·s complex viscosity
  - 430% elongation

- LMEE is thermally stable and exhibits little off gassing above package temperatures
  - <0.025% weight loss 175 °C after 1 hour

- LMEE achieves similar performance to S-TIM
  - <4 mm^2K/W at 30 µm

- To really know the performance we are looking to test this on a large dies >25mm x 25 mm packages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Thank You!
Feel free to reach out to me at kfeller@arieca.com