Solving Warping Issues with Novel Metal Compressible TIM

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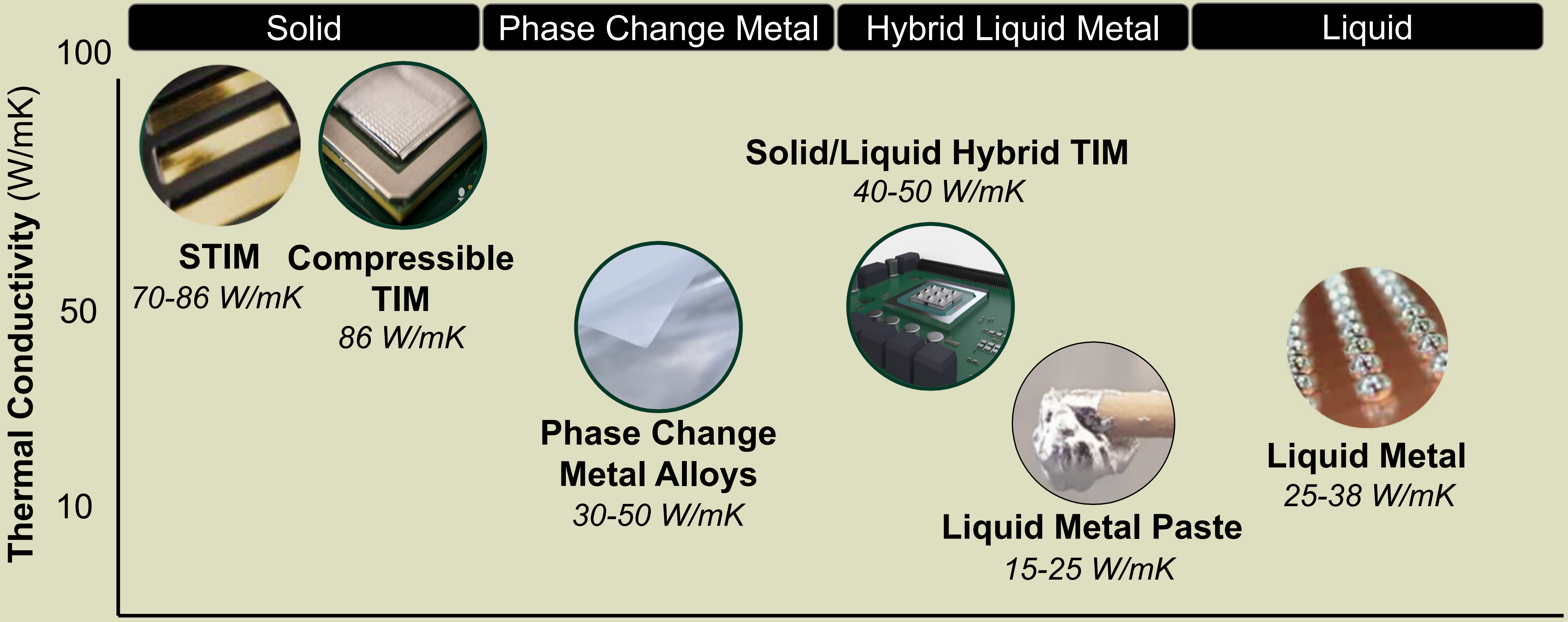
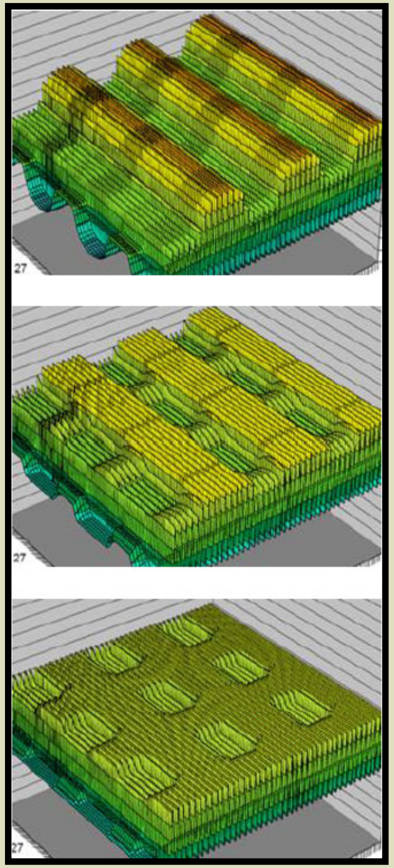
Metal TIMs

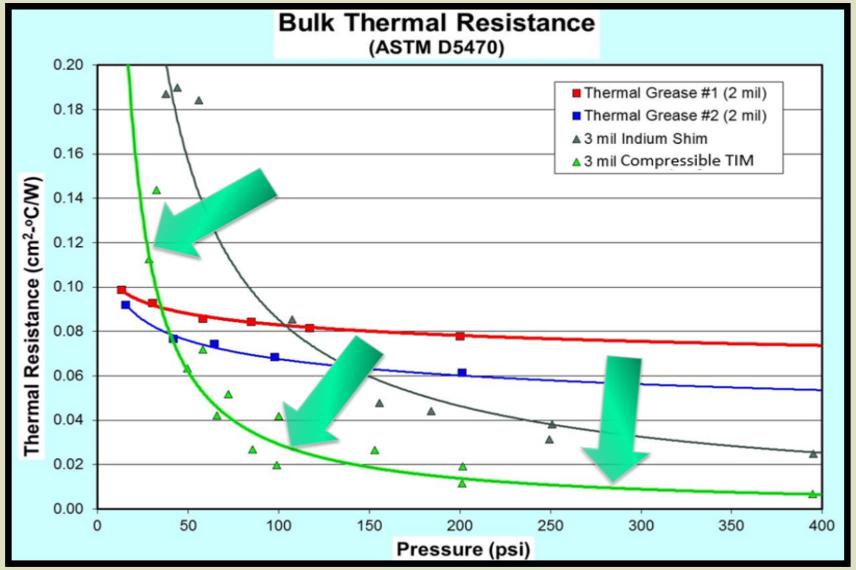

Solid
Phase Change Metal
Hybrid Liquid Metal
Liquid
Thermal Conductivity (W/mK)
100
50
10
STIM
70-86 W/mK
Compressible TIM
86 W/mK
Phase Change Metal Alloys
30-50 W/mK
Solid/Liquid Hybrid TIM
40-50 W/mK
Liquid Metal Paste
15-25 W/mK
Liquid Metal
25-38 W/mK

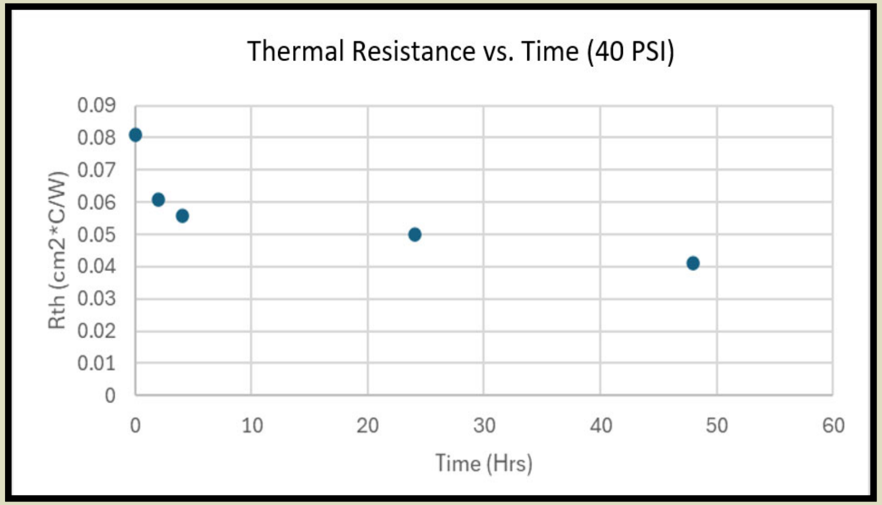
Compressible Metal TIM - Principles

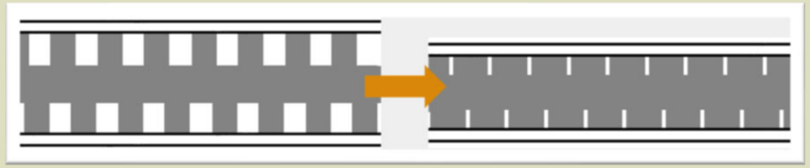
- Pattern applied to metal shim to form array of compressible columns
- Metal TIMs possess high thermal conductivity
  - Pure indium: 86 W/mK
  - TIM thickness has weak impact on thermal resistance
- Metal plastically deforms to the interfaces, thermal resistance decreases
  - Deformation through creep or optional preload



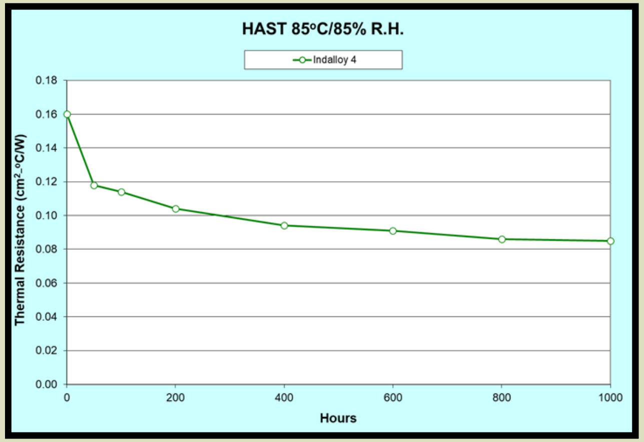
Compressible Metal TIM - Principles

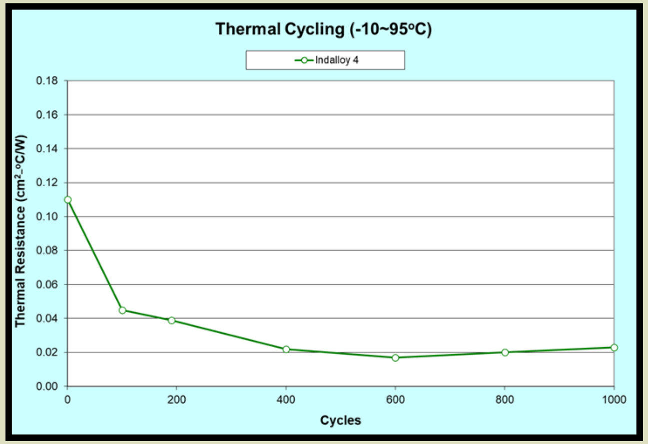


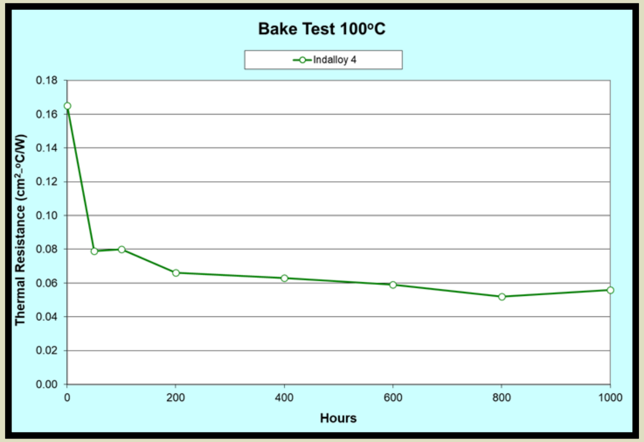




Compressible Metal TIM - Reliability







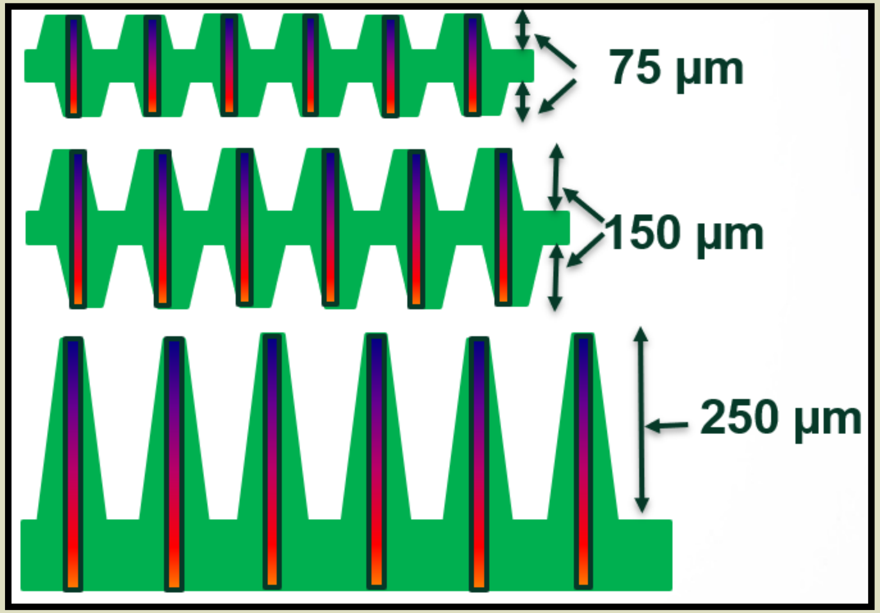
- TIM performance improves over time
- Pure indium metal – resistant to degradation
- No pump-out or bake-out
- Highly reworkable – easily removed, no residue

Compressible Metal TIM - Patterns

Pattern A

Pattern B

Novel Pattern X



- **Pattern A**: Designed for parallel interfaces with tight surface control
- **Pattern B**: Higher profile variant of Pattern A with 2X compressibility
- **Pattern X**: Alternative pattern geometry for optimized compressibility at lower pressures

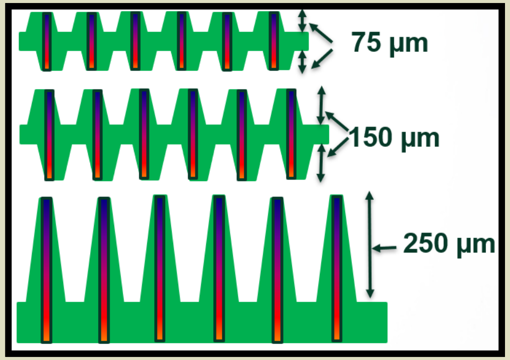
Compressible Metal TIM - Patterns

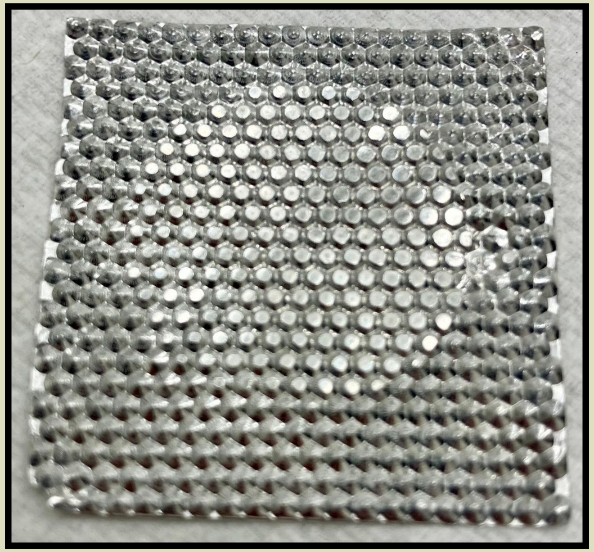
- Novel pattern is more compressible at lower pressures
- Recommended for non-planar/curved surfaces and applications with high CTE mismatch

Pattern A

Pattern B

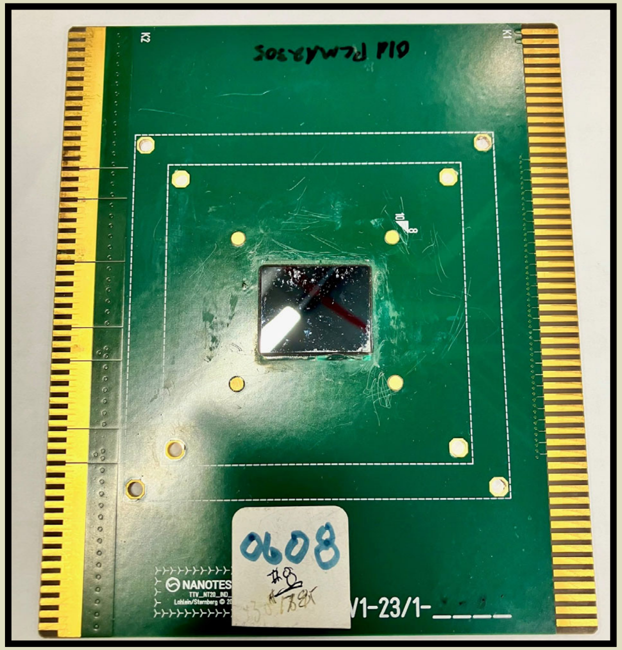
Novel Pattern X

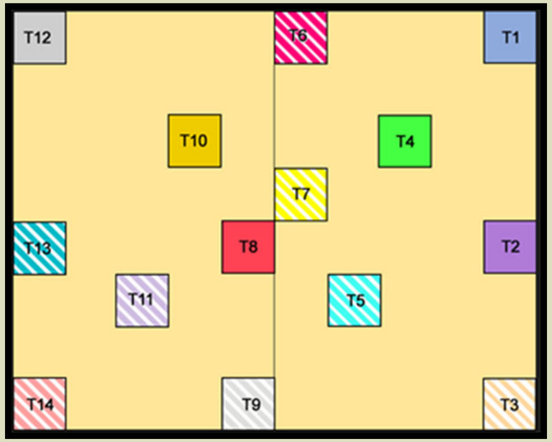




Thermal Test Vehicle (TTV) Assembly

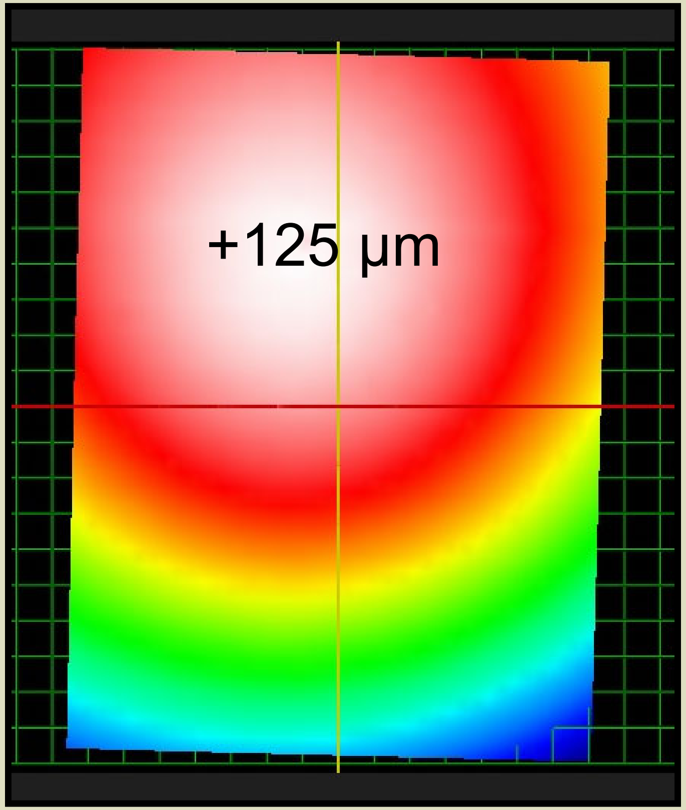
- 20 x 25mm die
- Cycling power up to 1400W
- Heat sink & chiller used for heat removal
- ~ 20 seconds/cycle (300W), ~40 seconds/cycle (1000W)
- 14 RTD locations





TTV Assembly – Die Profile

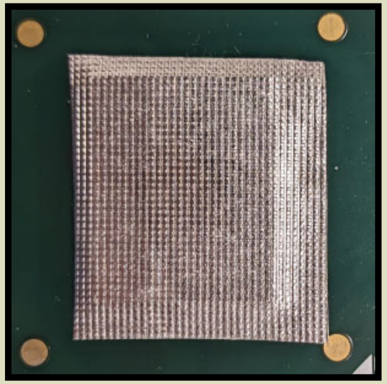
- Maximum crown 125 µm (5 mil)
  - Simulates non-coplanarity of production dies

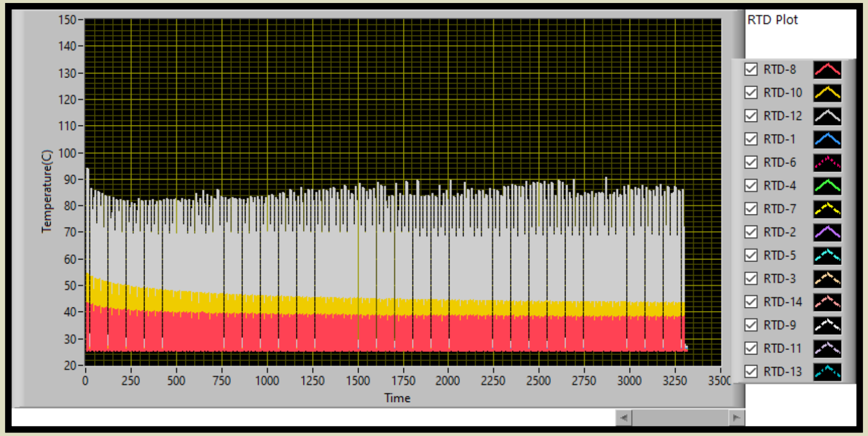


TestConX™

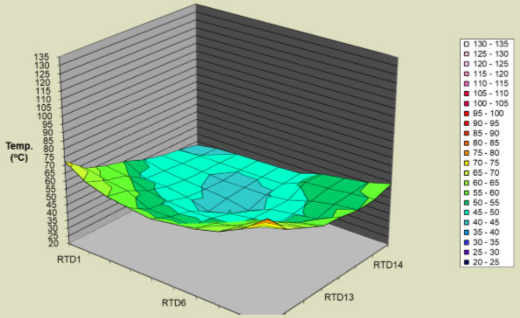
TTV - Pattern A, 50 psi, 0 – 300 W

- Good baseline resistance
- Limited compliance, corners never make contact

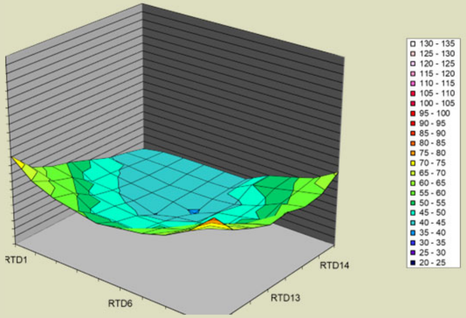




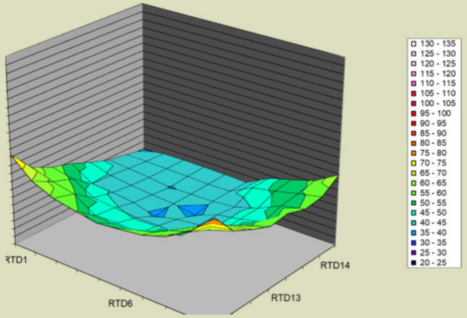
10 Cycles



50 Cycles

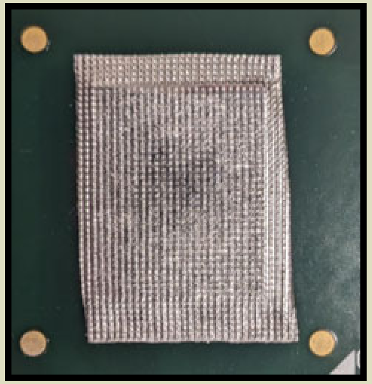


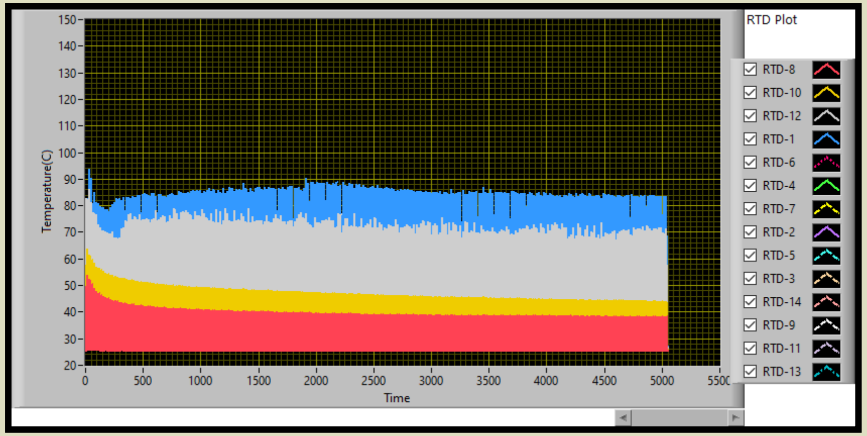
150 Cycles



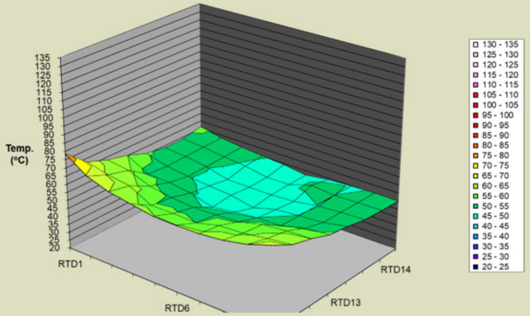
TTV - Pattern B, 50 psi, 0 – 300 W

- Good baseline resistance
- Improved compliance, corners never make contact

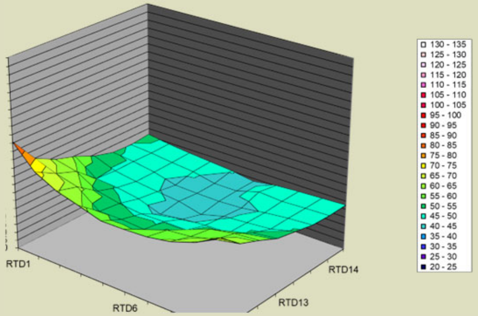




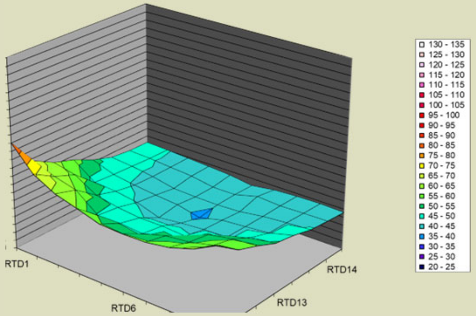
10 Cycles



50 Cycles

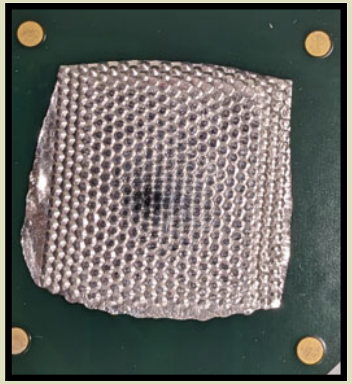


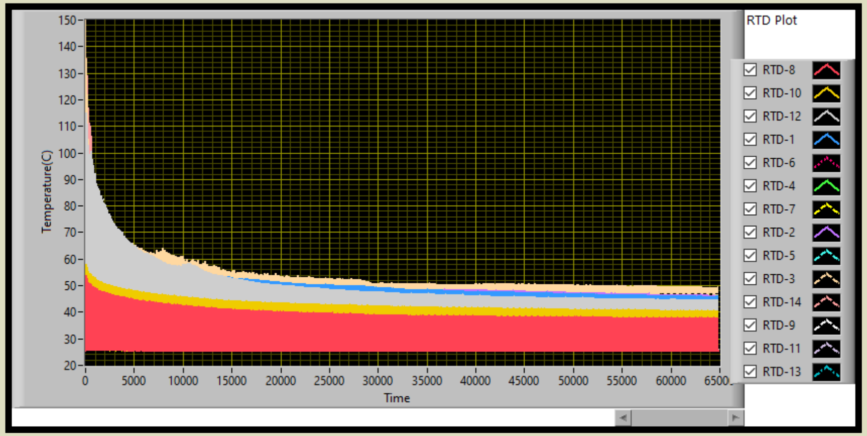
150 Cycles



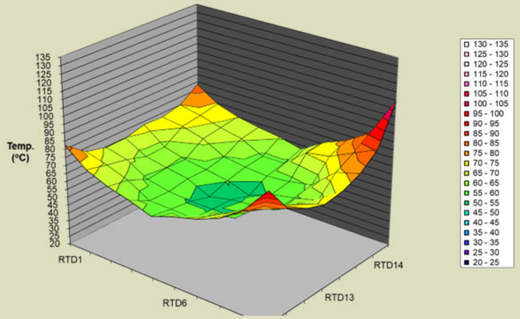
TTV - Pattern X, 50 psi, 0 – 300 W

- Improved baseline resistance
- High compliance, corners make efficient contact through cycling

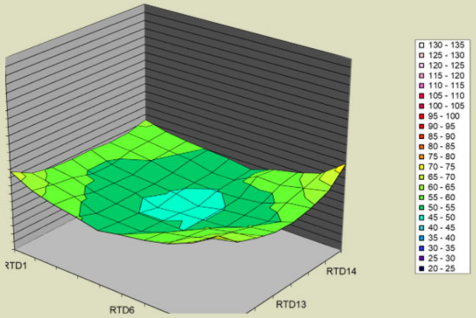




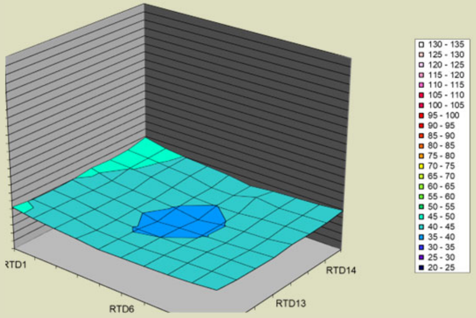
20 Cycles



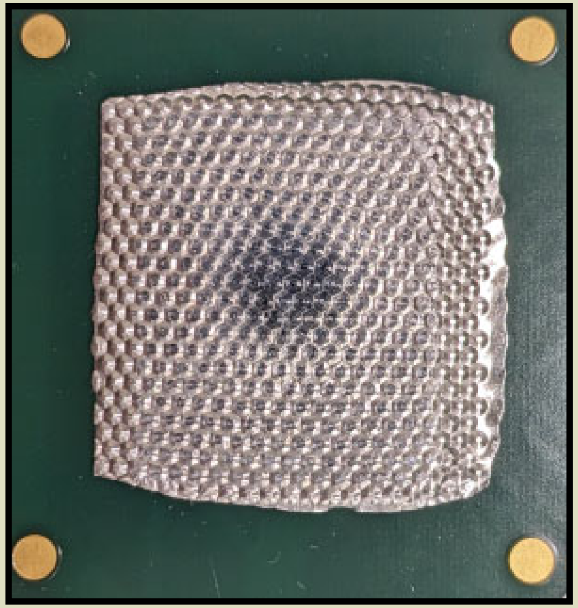
124 Cycles

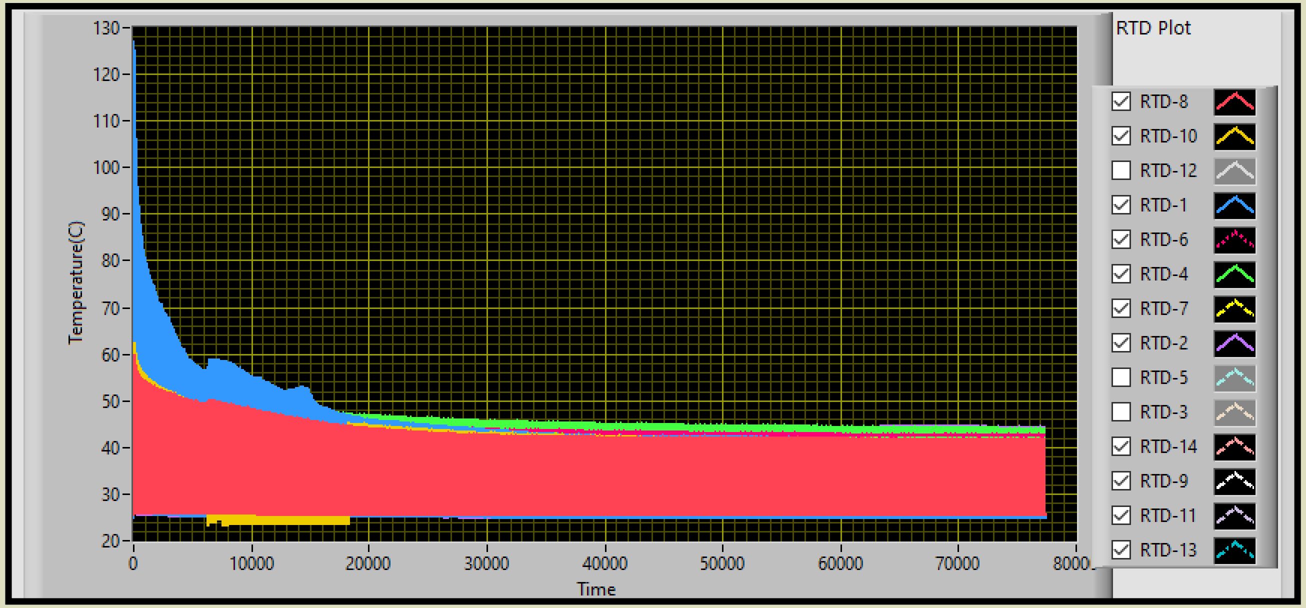


3240 Cycles



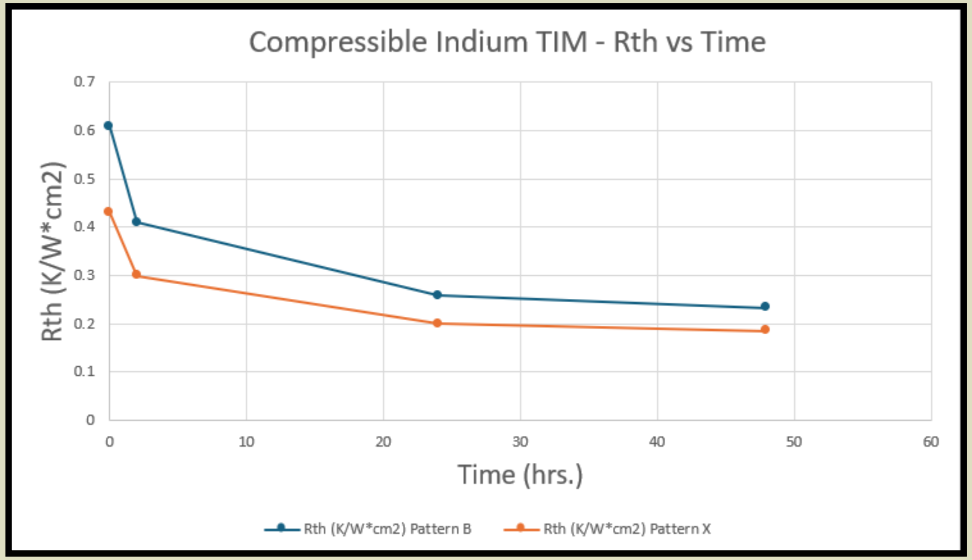
TTV - Pattern X, 30 psi, 0 – 300 W

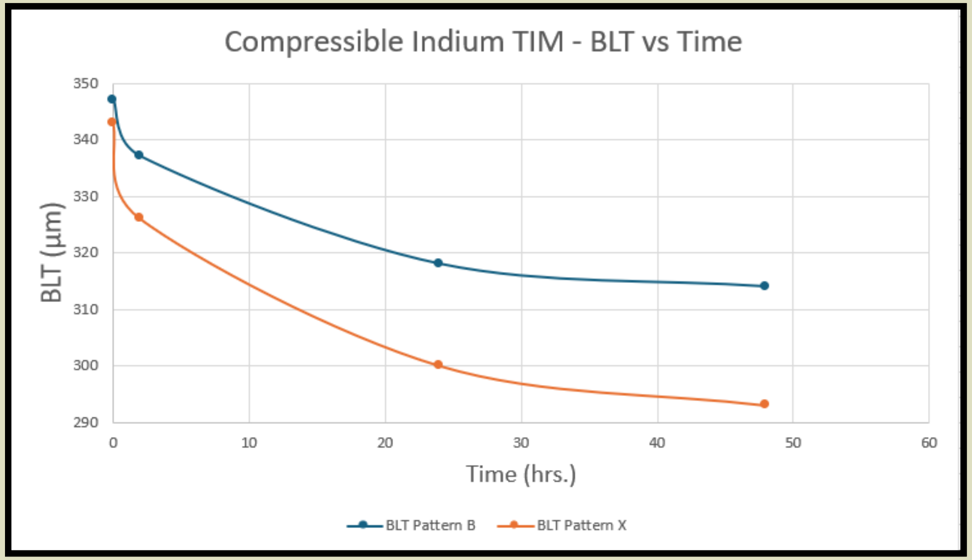




- At lower pressure, Pattern X exhibits lower, consistent temperature across die

TIM Pattern Compression



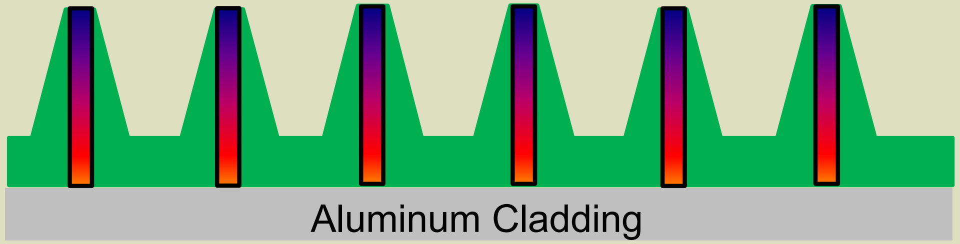


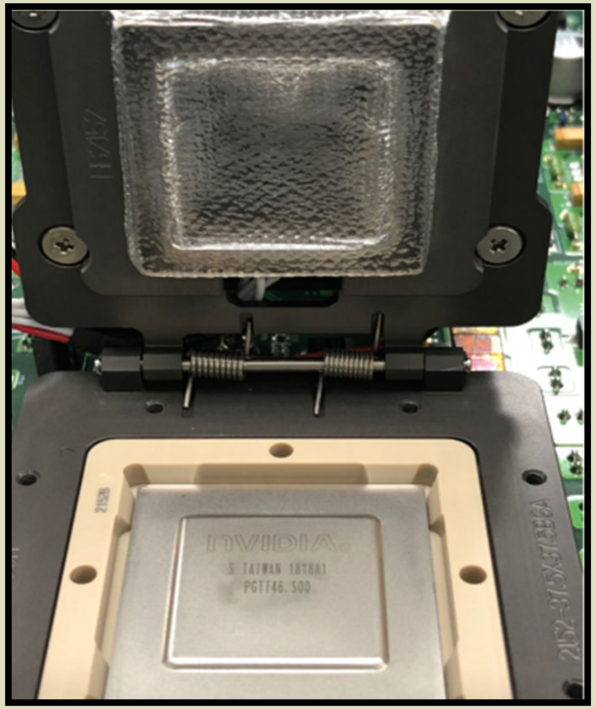
- 20 psi, 85°C, 0.012" overall thickness
- Novel Pattern X exhibits and maintains lower Rth and BLT over time
- Suitability for TIM1 and TIM1.5 applications

Compressible Metal TIM - Applications

Semiconductor Test and Burn-in

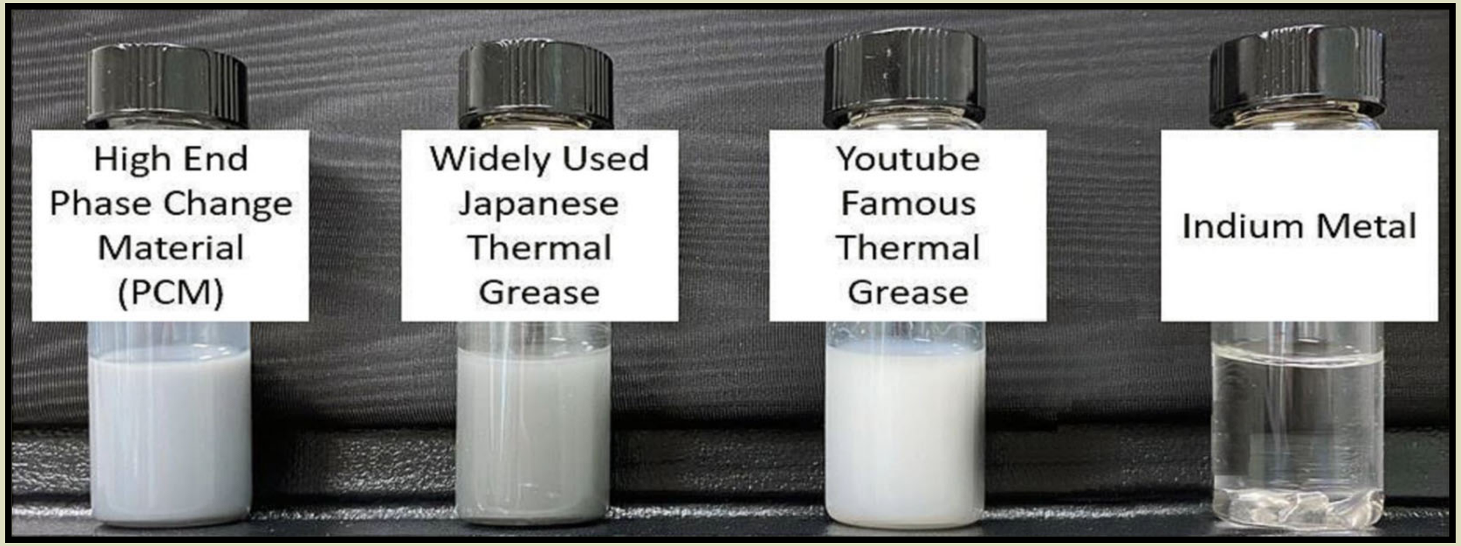
- Thin aluminum cladding added to TIM
- Prevents indium diffusion into device under test (DUT)





Compressible Metal TIM - Applications

Immersion Cooling



- Indium compressible TIMs will not dissolve in or contaminate immersion fluid

Compressible Metal TIM - Considerations

Alloy Selection

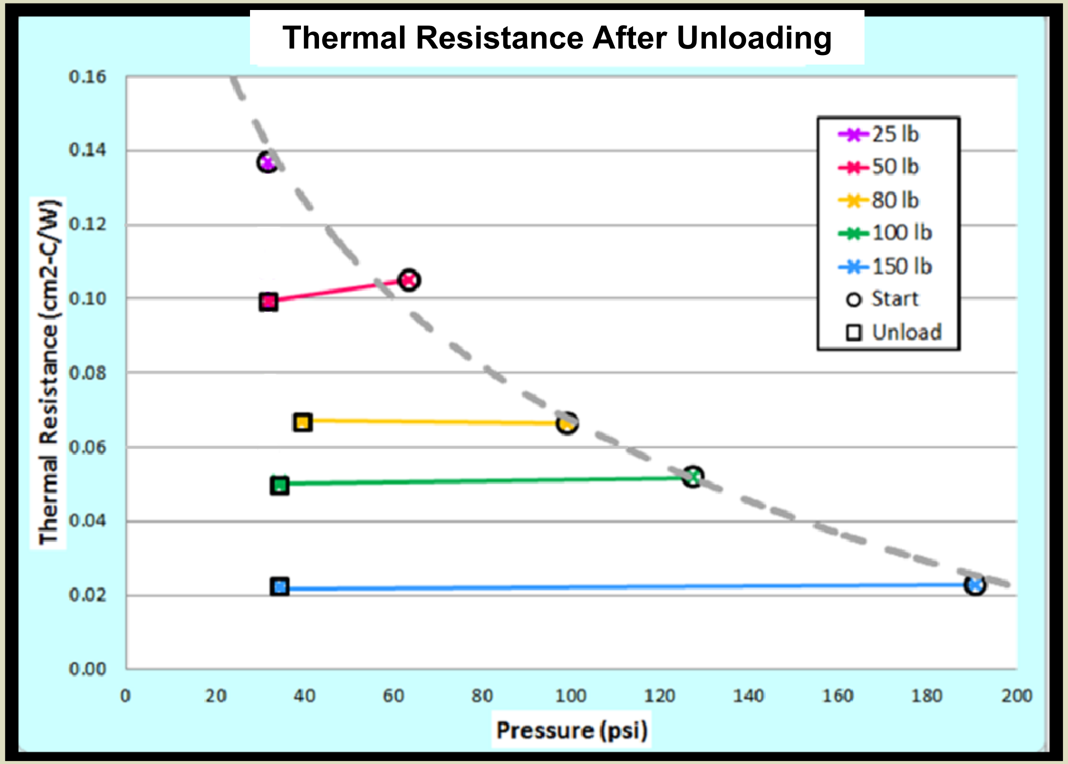
Alloy	Solidus (°C)	Conductivity (W/mK)	Estimated Flow Stress (PSI)	Suggested Pressure (PSI)
100 In	157	86	175	30 - 40
52In48Sn	118	41	310	30 - 40
90In10Ag	143	71	700	60-80
Sn+	232	73	1000-2000	80-100

- Pure indium recommended for most applications
- Alternative alloy considerations:
  - TIM area and mechanism of compression
  - Maximum TIM operating temperature

Compressible Metal TIM - Considerations

Pre-load Effects

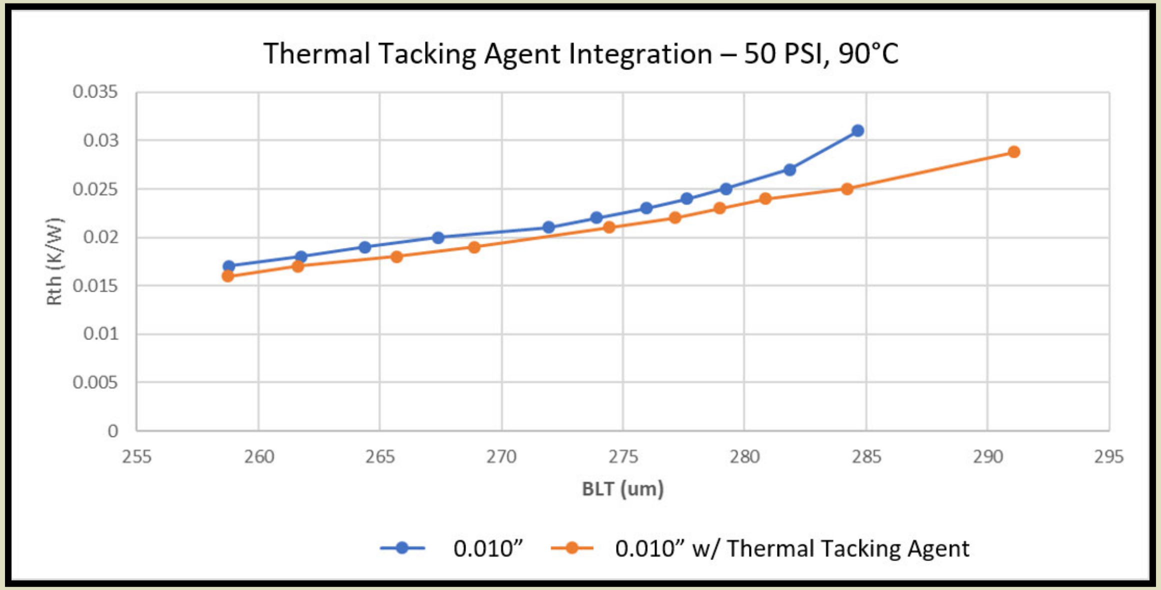
- Samples pre-loaded and unloaded
- Thermal resistance is determined by the contact formed at the peak load pressure
- Plastic deformation is maintained



Compressible Metal TIM - Considerations

Thermal Tacking Agent Integration

- Thermally conductive – improves thermal resistance (initial cycles)
- Maintains assembly alignment
- Not electrically conductive



Compressible Metal TIMs - Summary

- High-power applications require high-performing thermal interface materials
- TIM1 and TIM1.5 applications require metal compressible TIMs to have higher compliance at lower pressures
- Novel Pattern X TIM offers high compressibility, producing lower thermal resistance at lower pressures observed with curved, nonplanar surfaces

Contributions/Acknowledgements

[1] M. Lazić, S. Agarwal, "Liquid Metal Jetting for High-Performance Computing Applications", iMAPS 2024
[2] M. Lazić, "Liquid Metal TIMs," SEMI-THERM 2019.
[3] M. Lazić, R. McDonough, "High-Performance Phase Change Metal TIMs," IPC APEX Expo 2023
[4] M. Lazić, S. Agarwal, "A Jettable and Dispensable Liquid Metal Paste as a Thermal Interface Material", iMAPS 2023
[5] M. Lazić, "A New High Viscosity Liquid Metal Paste for Thermal Management", SEMI-THERM 2022.
[6] M. Lazić, A. Mackie, T. Jensen, D. Socha, "Solid Liquid Hybrid TIMs", PCB Carolina

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