Phase Change Metallic Alloy TIM2 Performance, Reliability and Deployment

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Outline

- PCMA & TIM2 Overview
- Testing
- Performance
- Reliability
- Interface Quality
- Deployment
- Next Steps
PCMA Overview

What is a PCMA?

- Phase Change Metallic Alloy or Low Melt Alloy (LMA)
- Alloys of Indium, Bismuth, Gallium, Tin
- Phase change typically 60-80°C
- Contains no organics
- May have a composite layer structure
- Typically in film/foil form
- High bulk conductivity
- High degree of wetting yielding low contact resistance
## TIM2 Overview

### Historic Qualities

<table>
<thead>
<tr>
<th>Material</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal Grease</td>
<td>• High bulk conductivity</td>
<td>• Pump-out</td>
</tr>
<tr>
<td></td>
<td>• Conforms to surface irregularities</td>
<td>• Phase separation</td>
</tr>
<tr>
<td></td>
<td>• No cure</td>
<td>• Migration</td>
</tr>
<tr>
<td></td>
<td>• Reworkable</td>
<td></td>
</tr>
<tr>
<td>Polymer-solder Hybrid (PSH)</td>
<td>• Good bulk conductivity</td>
<td>• Cure needed</td>
</tr>
<tr>
<td></td>
<td>• Conforms to surface irregularities</td>
<td>• Reflow needed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Delamination</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Non-reworkable</td>
</tr>
<tr>
<td>Phase-Change Metal Alloy (PCMA)</td>
<td>• High (metal) bulk conductivity</td>
<td>• Reflow needed</td>
</tr>
<tr>
<td></td>
<td>• Easy handling</td>
<td>• Pump-out</td>
</tr>
<tr>
<td></td>
<td>• Reworkable</td>
<td>• Migration</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Voiding</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Oxidation</td>
</tr>
</tbody>
</table>

Testing—Overview

- Packaged Thermal Test Vehicles (TTVs)
  - EOL performance data
- In-situ Test Vehicles (ITVs)
  - Reliability testing
Indigo Interface

Dimensions:

- Parts used for testing based on specific customer implementation

- Indigo requires moderate clamping force between heat sink and component (~20psi)

- BLT is between 3 and 4 Mils

- Indigo design includes adhesive seal around perimeter (~2mm)

- Studies show that heat distribution across a heat spreader forms a bell curve (majority of the heat near the center)
Testing—TTV Platform

Clamp Fixture
Leveling Foot (non-conductive)
Cooling Block
Foam Insulation
Thermocouple
TTV assembly & Socket
Thermal Test PWB
Clamp Pad (non-conductive)
Thermocouple

TC Meter
Heat/Cooling H2O System
Power Supply
4 Wire Ohm
Testing—TTV Details

Ceramic TTV for Performance Data:

- 4.84 cm² die area
- 100 Watts
- 2 Mil BLT (shims)
- Ni plated Cu lid
- Uniform heat flux
### Performance

<table>
<thead>
<tr>
<th></th>
<th>Particle Grease</th>
<th>PSH</th>
<th>Indigo2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Composition</strong></td>
<td>AL-filled polymer</td>
<td>PCMA within polymer</td>
<td>Indium-based</td>
</tr>
<tr>
<td><strong>Phase Change Temperature (°C)</strong></td>
<td>N/A</td>
<td>~30</td>
<td>~60</td>
</tr>
<tr>
<td><strong>Thermal Conductivity (W/mK)</strong></td>
<td>6</td>
<td>4</td>
<td>~ 20</td>
</tr>
</tbody>
</table>

In-situ performance data

40-50% reduction of $\Theta_{JC}$

![Graph showing $\Theta_{JC}$ values for Particle Grease, PSH, and Indigo2]
Reliability
In-Situ Test Vehicle (ITV)

- Cooling Tank
- Pump
- Chiller
- COTS H₂O Block
- Clamping Bolts (4x)
- RTDs (2x Lid; 2x H₂O block)
- TIM2 (Indigo2)
- Cu Lid
- TIM1
- Heater (in place of die)
- Athlon XP (die removed)
- Athlon MB PCB (cut down)

- Precision Compression Springs (30PSI on TIM2)
- RTD DAQ
- Heater Power Supply

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Reliability

In-Situ Test Vehicle (ITV)

- Wells drilled into lid and waterblock to accommodate RTDs
- 2 wells in lid, 2 in waterblock
- Precision 4-wire RTDs
Reliability
In-Situ Test Vehicle (ITV)

- Vehicle Designed to simulate specific clamping force and heat source parameters during in-situ reflow
- Replicates CTE and thermomechanical forces on interface throughout environmental testing
## Environmental Test Goals

<table>
<thead>
<tr>
<th>Qualification Test</th>
<th>Test Condition</th>
</tr>
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<tbody>
<tr>
<td>Temperature Cycling</td>
<td>0°C to 100°C, 10°C/min. ramp, 10 min. dwell, 1000 cycles</td>
</tr>
<tr>
<td>Elevated Temp. Bake/Soak</td>
<td>125°C, 500 hrs</td>
</tr>
<tr>
<td>Temperature and Humidity</td>
<td>85°C/85% RH, 500hrs</td>
</tr>
<tr>
<td>Cold Cycle</td>
<td>24°C to -30°C, 10°C/min. ramp, 30 min. dwell, 3 cycles</td>
</tr>
</tbody>
</table>

Reliability Results-T/C

- JEDEC-J, 0-100°C 1000 Cycles
- Results for 2 parts
- BLT is reduced during first 100 hot cycles
- Measurement error < 5% between RTD, meter and comparative measurements

% Change in $\Theta_{cs}$ per TC Cycle

% Change in $\Theta_{cs}$

Thermal Cycles

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Reliability
Results-85°C/85% RH

- 85°C/85% RH for 500 Hours
- BLT is reduced during first 100 hours
125°C for 500 Hours

BLT is reduced initially

Actual degradation from EOL (<1%)

Minor intermetallic formation
Reliability
Results-Cold Cycle

- Cold Cycle
- -30 to 24°C, 10°C/min ramp
  30 min dwell
  3 cycles total
- 0.6% change in $\Theta_{CS}$ within measurement error
Interface Quality
Void Fraction—EOL

- Typical void fraction < 2%
- On close examination of surface, texture of lid and heat sink visible on interface surface

Interface removed from ITV at EOL

Corner torn during ITV disassembly
Deployment
Reworkability

- 1.5 in² component area
- Ambient temperature
- 7 lbs/min. ramp (tensile loading)
- 23.3 psi (160 kPa) break load
- Similar to PCM > Tmelt

Next Steps

- Shock/Vibe Testing
- Corroborate existing data with larger lot size
- Extend proven architecture to new applications: Lasers, power semiconductors, RF amplifiers, microprocessors, etc.
PCMA TIM2 Summary

- Design meets performance goal of 40-50% reduction of $\Theta_{CS}$ over greases or PSHs
- Qualifies TIM2 environmental testing
- Void fraction <2%
- Historic disadvantages of PCMAs have been overcome
- Reworkable
- Scalable to other applications
Thank you.

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