Design of a Thermal Interface Material (TIM) Cycling Reliability Test Program for Semiconductor Test Requirements

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Purpose: TIM Contact Cycle Testing for Semiconductor Test and Burn-In

This presentation describes a reliability testing program for thermal interface materials (TIMs) for semiconductor test and burn-in applications:

- Survey, semiconductor test industry requirements for test parameters;
- Mechanical contact cycling and thermal resistance measurement of TIMs;
- Four program test phases, to test under increasingly rigorous cycling;
- Test results, Phases I - IV;
- Analysis.

The overall purpose of this test program is to evaluate durability of selected TIMs under mechanical contact cycling equivalent to requirements for semiconductor test.

Thermal Interface Materials for Semiconductor Test and Burn-In

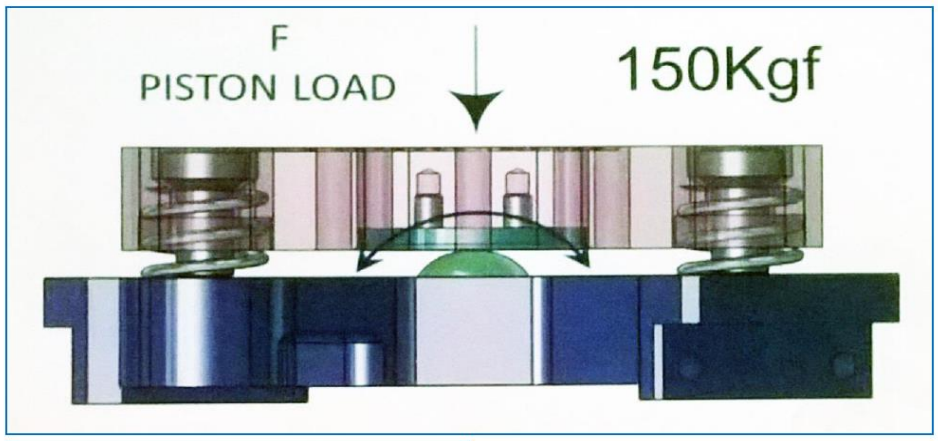
Specialized TIMs for semiconductor test and burn-in requirements:

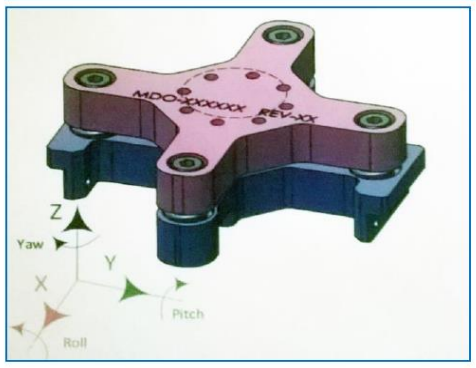
- Required thermal resistance value to meet a package heat transfer goal;
- Zero residue or marking of Device Under Test (DUT) for each contact;
- Multiple contact cycles: Contact, pressure, and heat applied for each test cycle per DUT;
- Goal: Durability, to survive > 1,000 cycles.

ASTM D 5470-17 industry standard for TIM thermal performance testing:

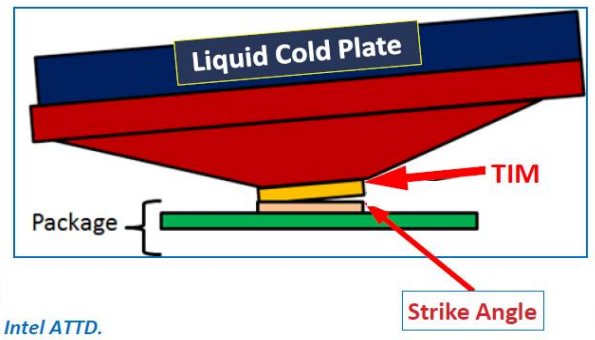
- Berliner Nanotest TIMA 5 system selected;
- Servo-driven, automatable;
- Precise contact, pressure, heat flow capable.

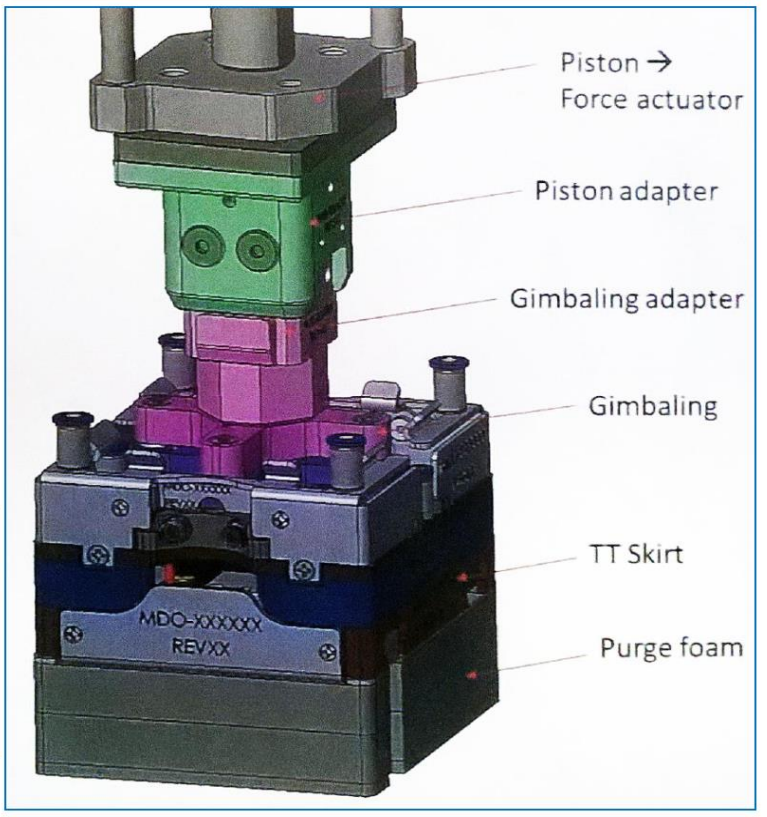
Semiconductor Test System Head Assemblies -- Examples





Gimbaled Test Head Illustration





Source: DS&A LLC. Above: Intel IDC (Israel). Right: Intel ATTD.

Semiconductor Test Cycling Parameters

Semiconductor test engineers were surveyed to determine test parameters:

Table 1. Thermal /Mechanical Cycling Test Parameters

Organization	Test Pressure Reported	Test Temperature Range Reported (°C)	Dwell (Seconds)
Company A	11.7 bar (170 PSI)	25**/100	60
	11.7 bar (170PSI)	100	60
Company B	6.7 bar (100 PSI)	-	60
Company C	-	120	-
Company D	-	100	-
Company E	-	80	60
Company F	4.1/6.7 bar (60/100 PSI)*	105**/125	-
	6.7 bar (100 PSI)*	105**/125	-

*Note: * Pressure applied dependent upon die or package contact area. ** Initial value. Source: DS&A LLC.*

Test Program: TIM Contact Cycle Testing for Semiconductor Test

Test program with four phases for TIM thermal and reliability testing specific to semiconductor test and burn-in:

Table 2. Thermal /Mechanical Cycling Test Program Design

Program Phase	Purpose	Test Head Configuration*	Operating Temperature (°C)	Data Output
I	Baseline Values	Parallel	70 – 95	R_{th}**, Thickness Change,*** 1,000 Contact Cycles
II	Strike Angle	Upper Body: Strike Angle	70 – 95	R_{th}**, Cycle Count
III	Strike Angle/Elevated Temperature	Upper Body: Strike Angle at Elevated Temperature	125	R_{th}**, Cycle Count
IV	Baseline Values	Parallel	95	R_{th}**, Thickness Change,*** 5,000 Contact Cycles

*Notes: * Test head configuration and test system design per ASTM D 5470-17 thermal interface material testing methodology. Use of this test system and methodology is intended to provide industry-standard baseline thermal performance values.*
*** Thermal resistance value is the principal thermal performance value for a TIM and uniform, stabilized values indicate an appropriately stable testing system.*
**** Thickness change data is intended to provide indication of a stable test cycling process for baseline data.*

Thermal/Mechanical Test System Design

Testing utilized a commercial ASTM D 5470-17 (modified) test stand:

Table 4. Thermal /Mechanical Cycling System Design	
Property	**Value**
System	Berliner Nanotest TIMA5
Upper Reference Body (Heater Bar)	125°C
Lower Reference Body (Liquid Cold Plate)	75°C
Sample Temperature	95°C
Clamping Force Method	Servo Automated
Clamping Force Applied	500kPa (5.0bar/72PSI)
Temperature Measurement	In situ
Thickness Measurement Under Force Applied	In situ

Note: Uniform single clamping force applied for all materials. Source: Berliner Nanotest und Design GmbH.

Test Data, Phase I: Parallel Test Heads

Phase I testing of all three TIM types successfully passed 1,200 cycles:

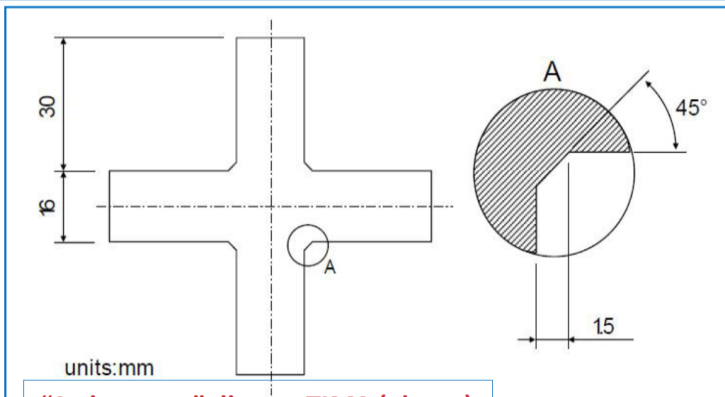
- HSMF-OS*: 0.051mm (0.002”)-thick aluminum foil, coated one side only with non-silicone thermal compound. Applied with Al surface facing DUT.
- 99.99% flat indium foil [0.30mm (0.012”) thickness, including clad (one side only) with 0.1µm (0.0005”) aluminum]. Applied to test head with aluminum surface facing DUT.
- Indium Corporation Heat-Spring® HSK** patterned 99.99% indium foil, clad one side only with 0.1µm (0.0005”) aluminum . Total thickness: 0.559mm (0.0220”). Applied to test head with bare aluminum surface facing DUT.
- Testing at 95C to establish baseline data with *parallel test heads.*

*Note: ** Indium Corporation HSMF-OS. Heat-Spring® is an Indium Corporation Registered Mark. US Patent granted.*

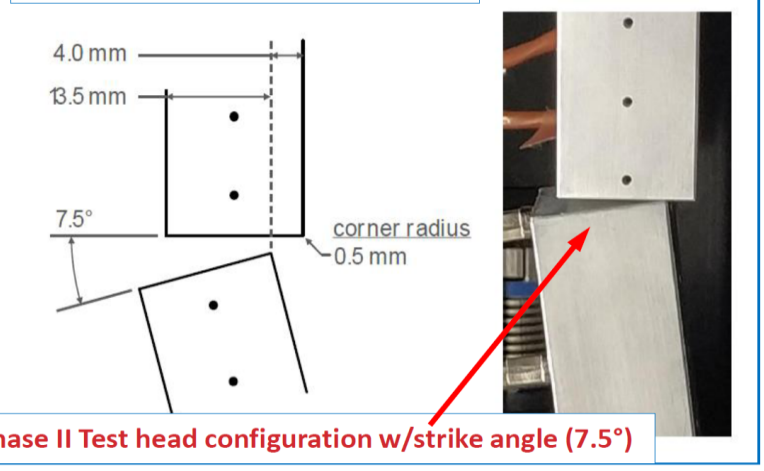
Phase II System Test Design: Strike Angle

Test heads were adapted for this mechanical cycling test program to fit existing test stand.

- Test head (lower) strikes test head (upper) at 7.5° angle, to mimic actual conditions;
- TIM applied to upper test head;
- Nanotest TIMA5 test stand is servo-driven, enabling use of this test stand to test with automated mechanical cycling for repeated, precise contact control.



“Swiss cross” die-cut TIM2 (above)

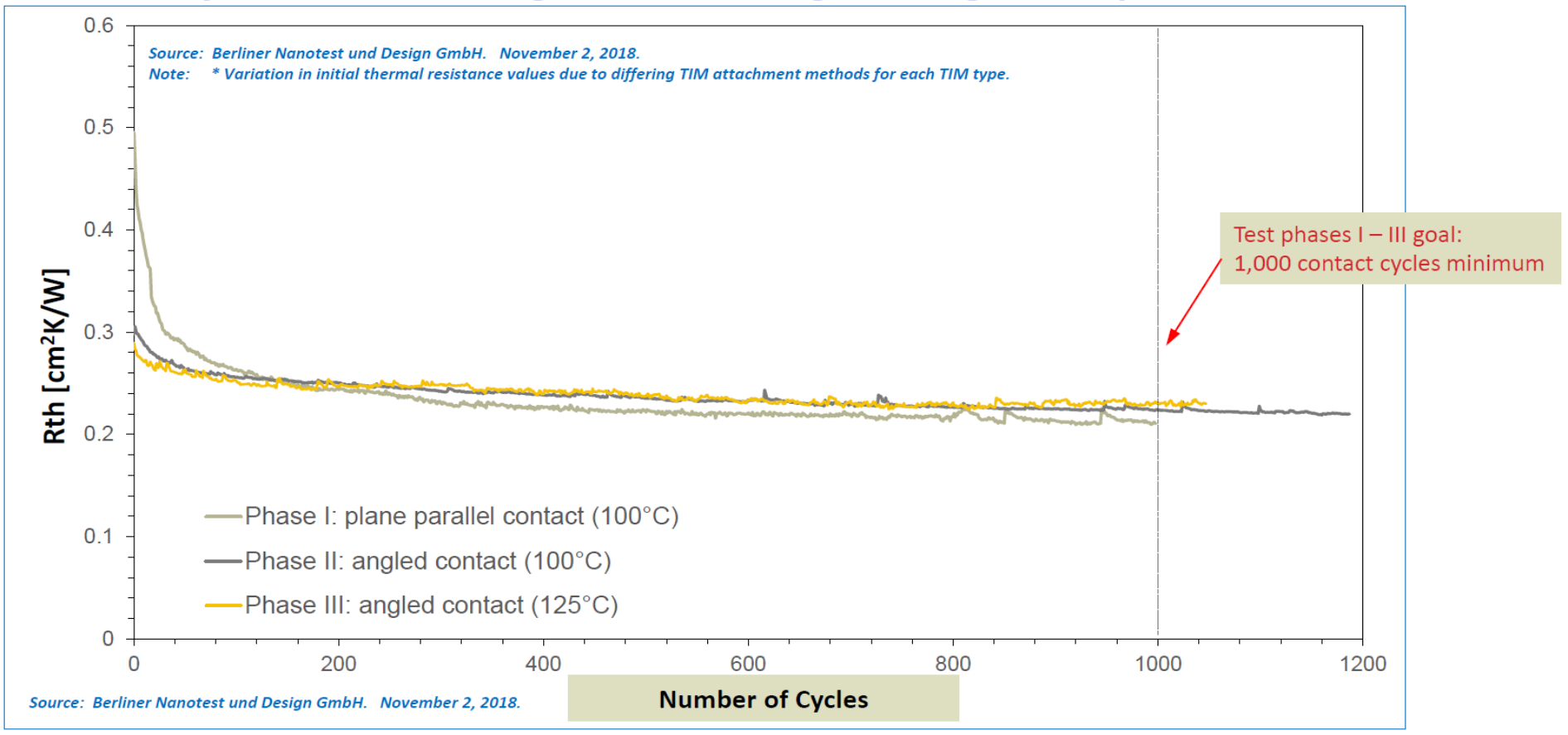


Phase II Test head configuration w/strike angle (7.5°)

Phase III System Test Design: Strike Angle + High Temperature

- 125°C test temperature applied at the test head.

Phase III System Test Design: Strike Angle + High Temperature



Summary

Thermal interface materials (TIM) are integral for adequate heat transfer from a semiconductor source to an external environment.

- Specialized TIM materials can be characterized as "well-performing" when measured against challenging requirements for critical applications.

A range of metallic TIMs have been developed for specialized test applications requiring mechanical durability in challenging conditions.

- An automated mechanical cycling reliability test program has been designed to reproduce semiconductor test conditions to determine robustness:
  - All materials tested passed all Phases I - IV cycling test goals successfully.
  - Test data and analyses are reported

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Test equipment, thermal test wafers, and thermal test vehicles (TTVs) for semiconductor thermal material characterization.