Measuring the Performance of Thermal Interface Materials in an In-situ Test Environment

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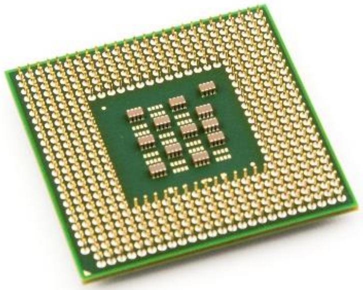
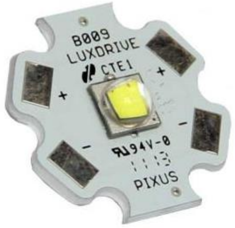
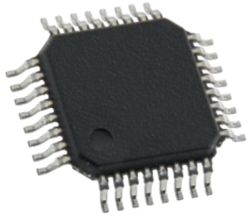
Virtual Conference

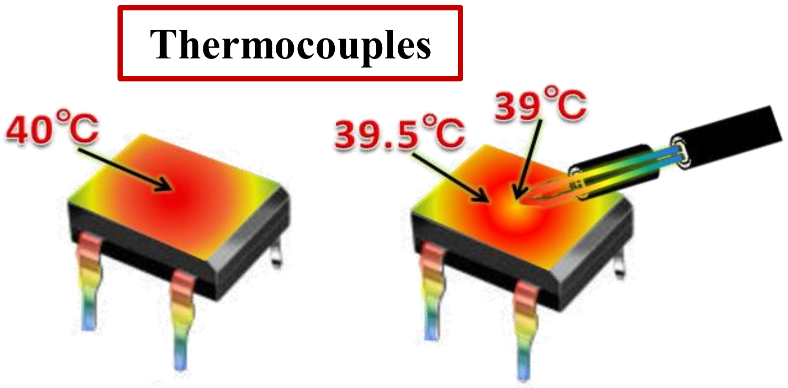
Simcenter Micred T3STER Technology - The Challenge

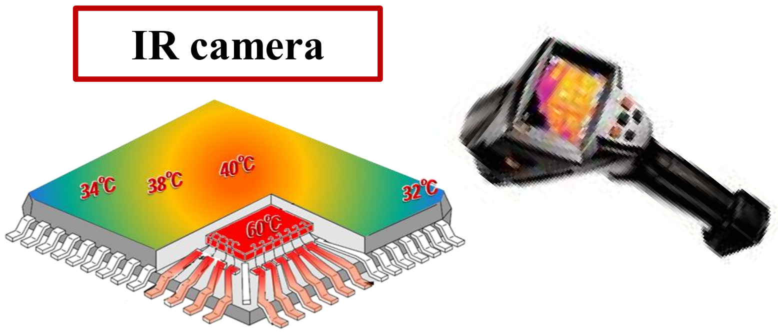
- Thermal Structure
  - Junction to Ambient metrics
  - Junction to Case
  - Resistance and Capacitance in layers
  - Accurately and consistently

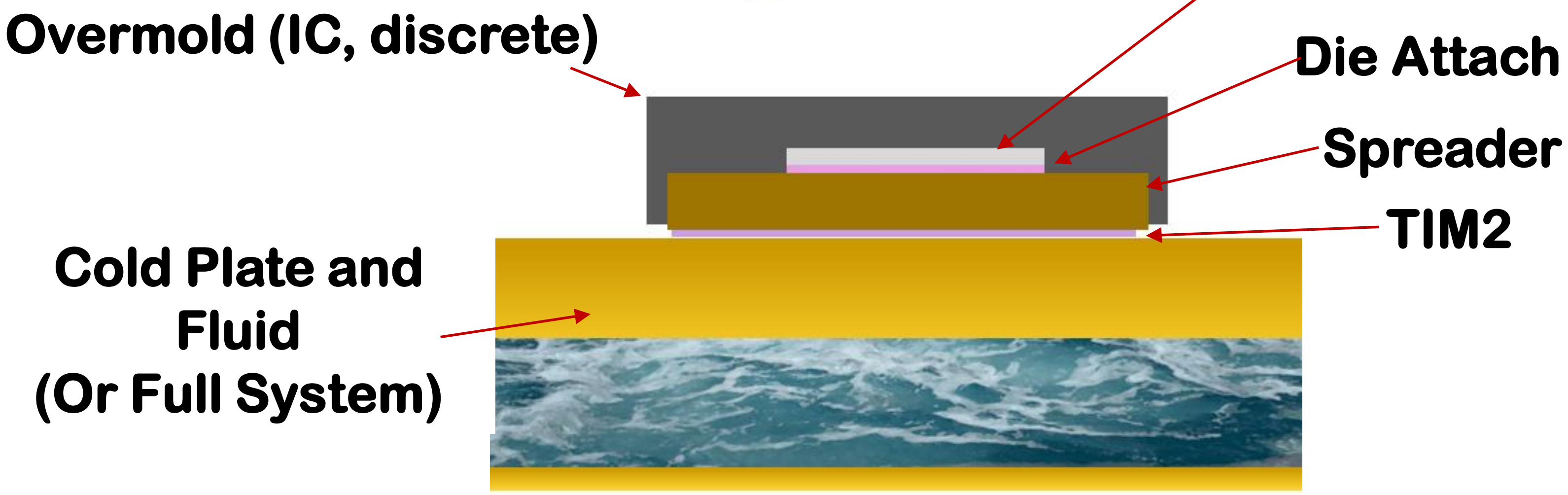










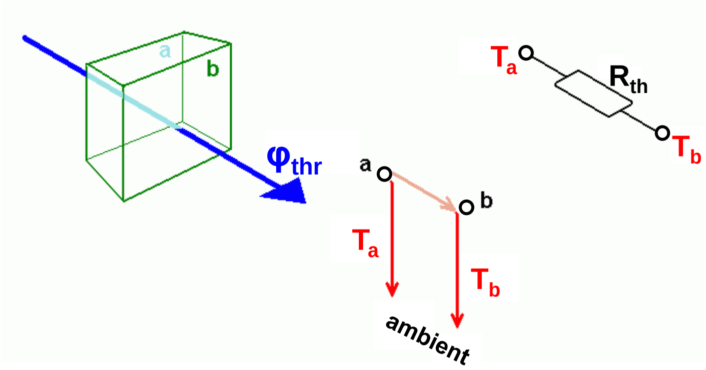


Thermal Metrics

Thermal systems are built up of different, typically stacked material regions

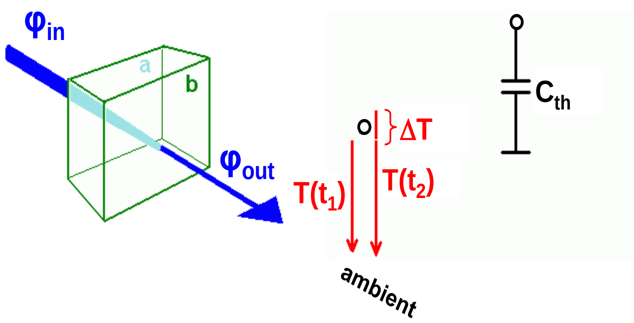
From the active area perspective the contribution of each layer can be modeled with a thermal resistance (R_{th}) and thermal capacitance (C_{th}) value.

Thermal Resistance

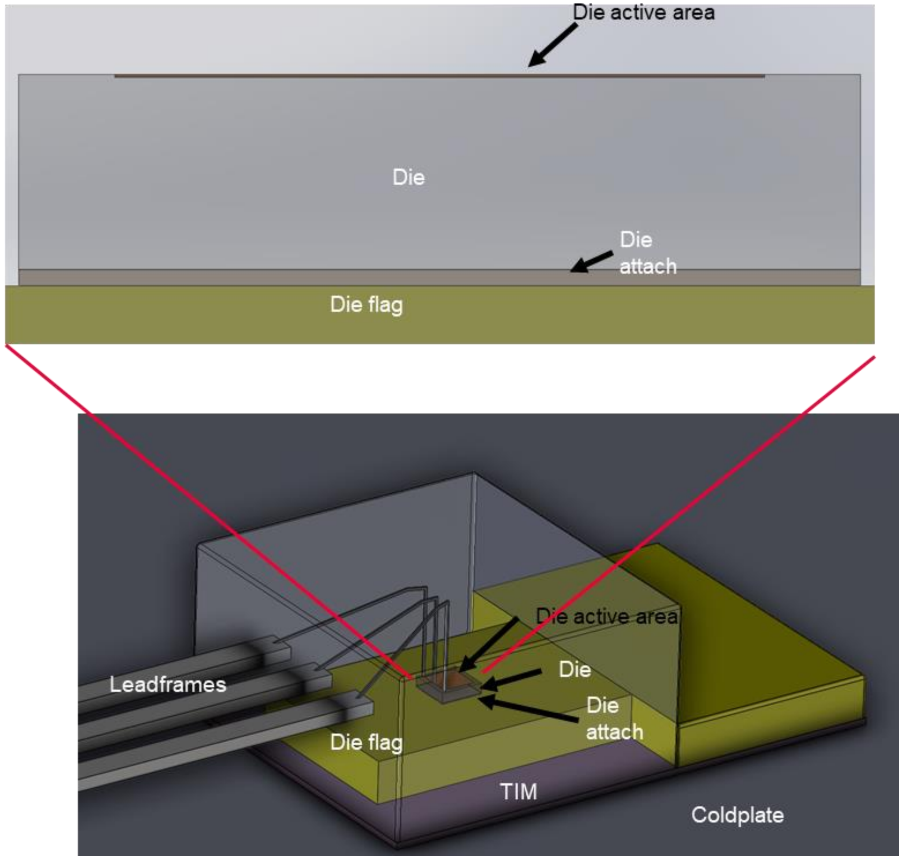


$$T_a - T_b = PR_{th} = P\left(\frac{1}{\lambda}\frac{dx}{A}\right)$$

Thermal Capacitance



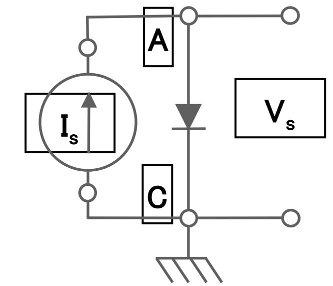
$$C_{th} = c_V \cdot V = c_V \cdot dx \cdot A$$

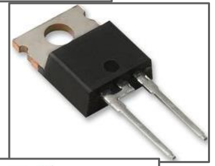


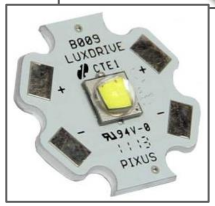
Detailed Method for Describing a Thermal Path

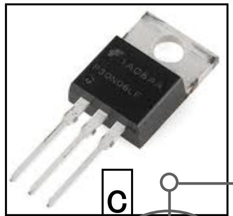
JEDEC 51-1 Identify TSP*

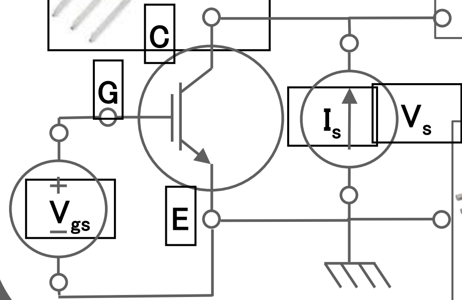
*Temperature Sensitive Parameter

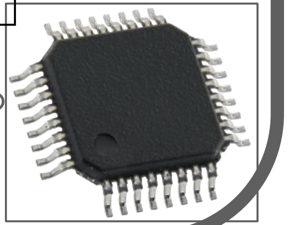




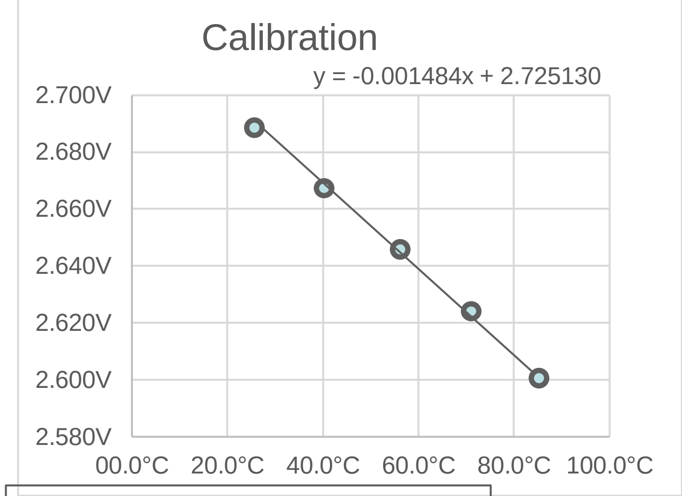


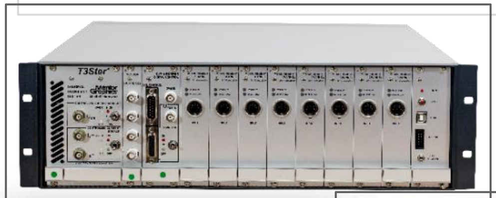






Calibrate the TSP

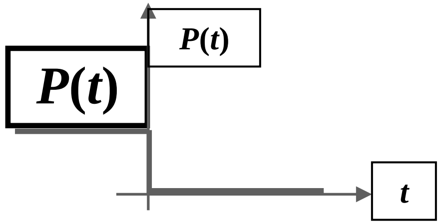


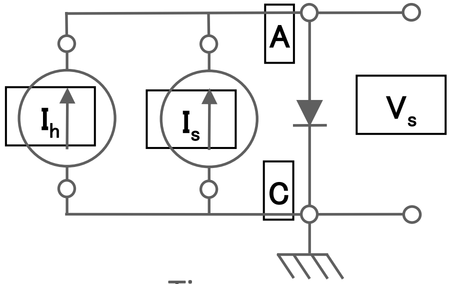


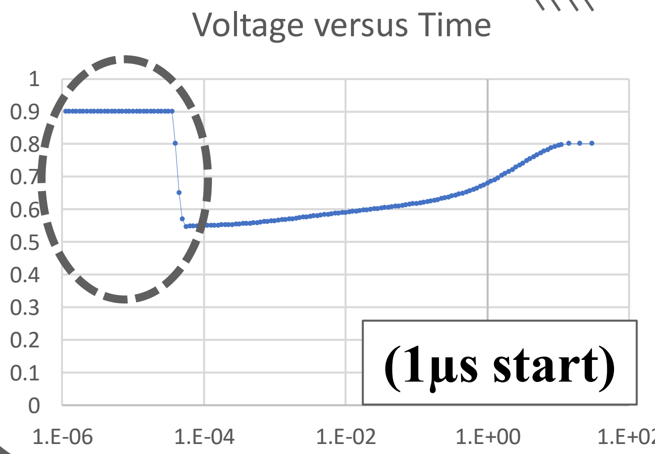
+/-0.01C

Isothermal Environment; coldpate or oven

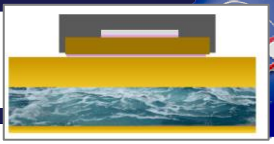
Apply Heating Current



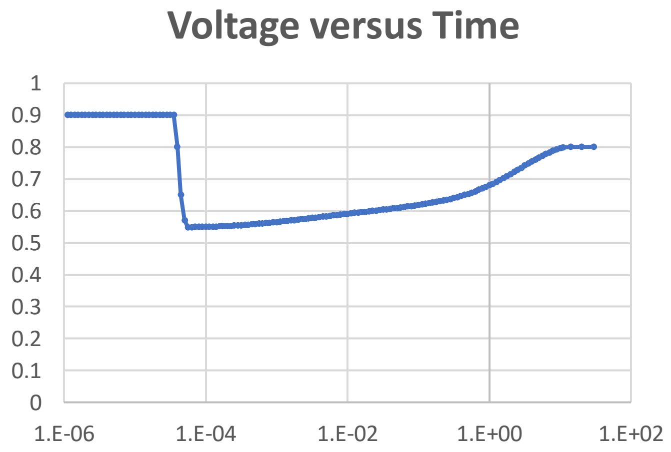


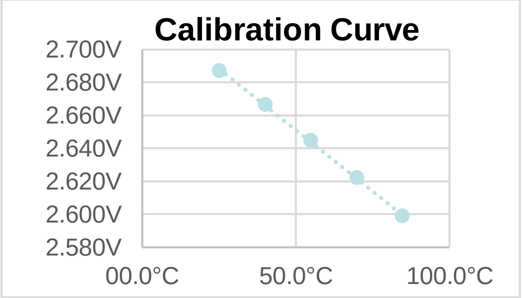


Detailed Method for Describing a Thermal Path



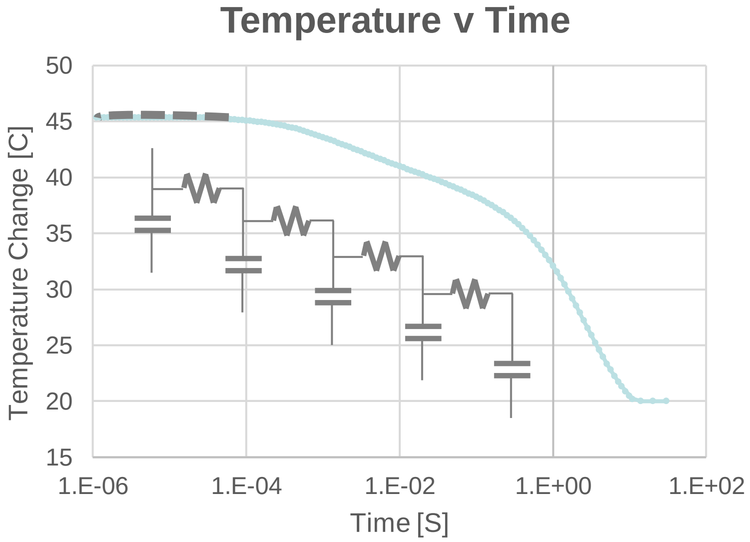
Convert Voltage to Temperature





Convert Temperature to Structure

$$T(t) = P(t) \otimes^{1} W(t)$$



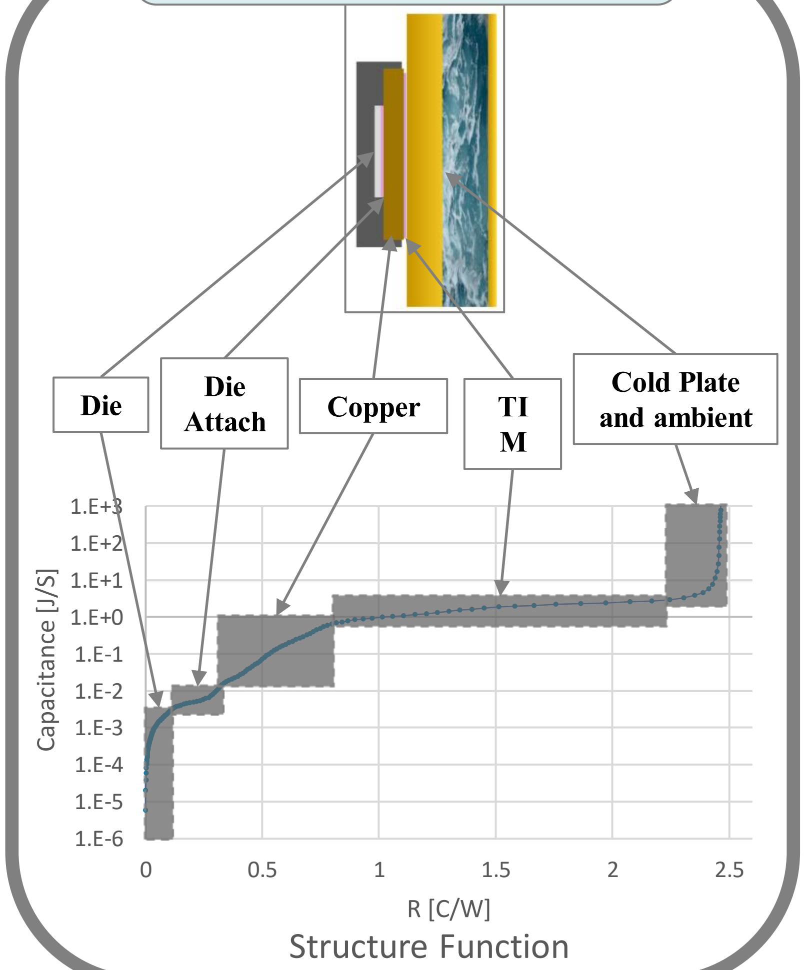
$$W(t) = T(t) \otimes^{-1} P(t)$$

P=Power

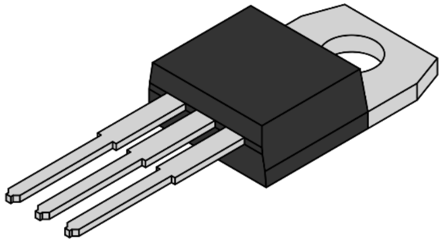
T=Temperatur

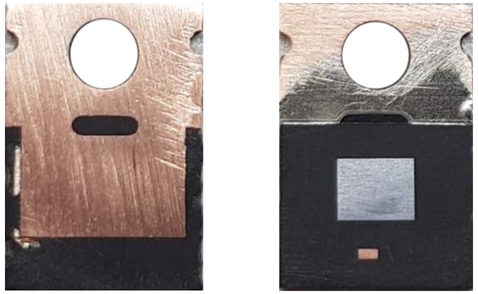
W=Structure

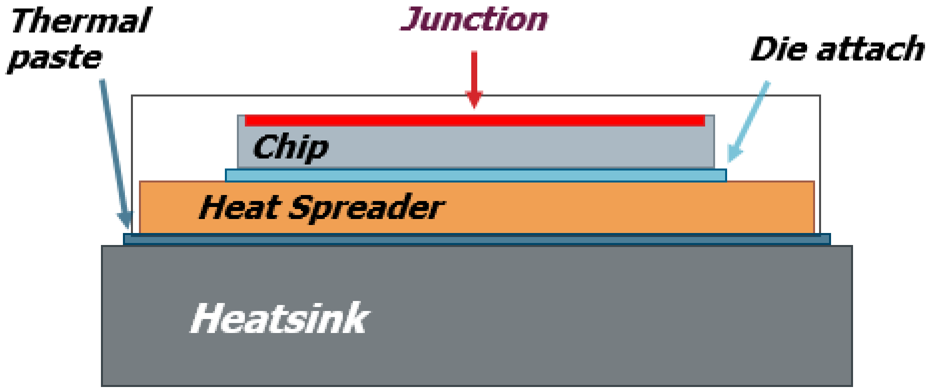
Interpret the Structure Function



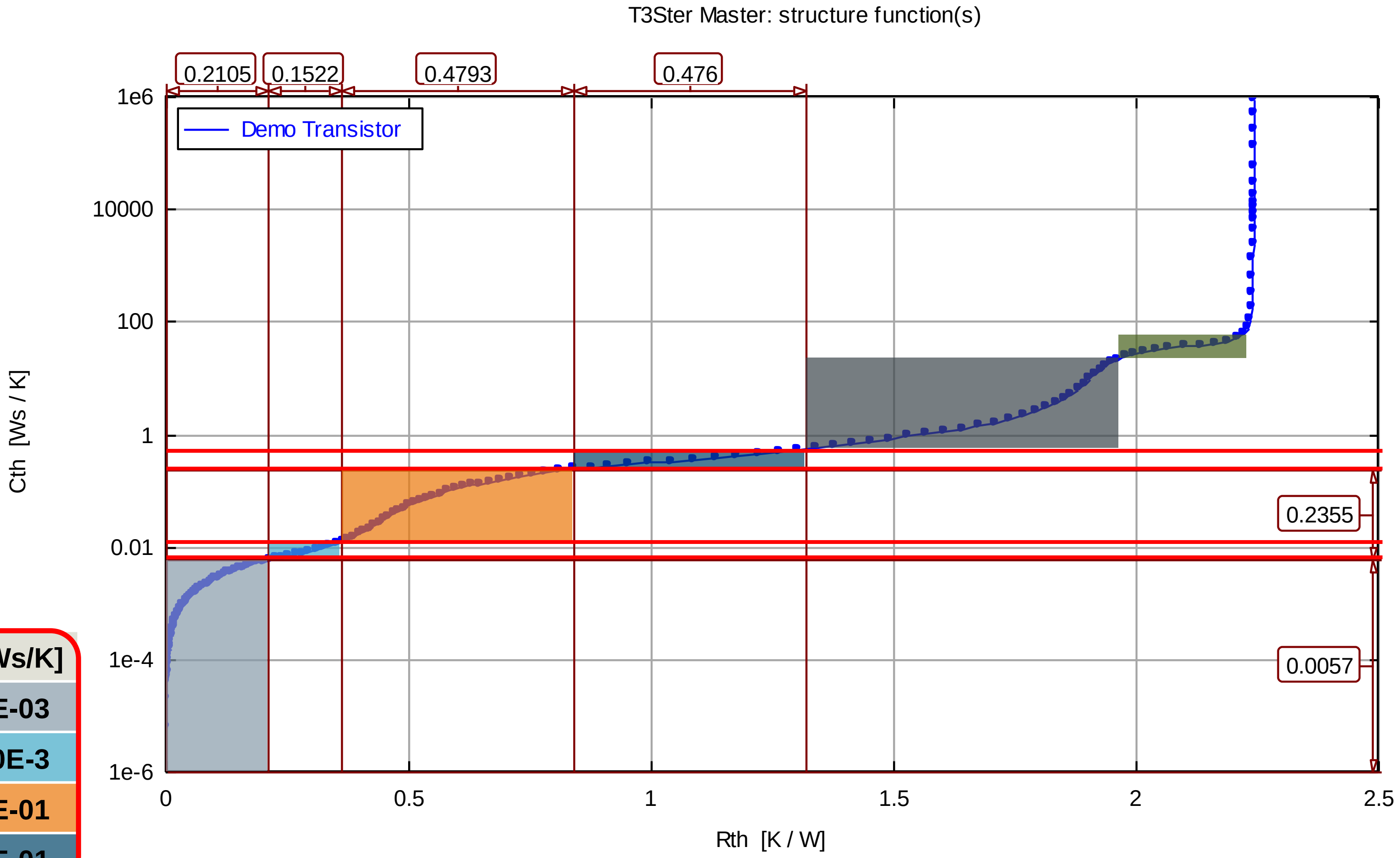
Thermal Characterization Utilizing Structure Functions







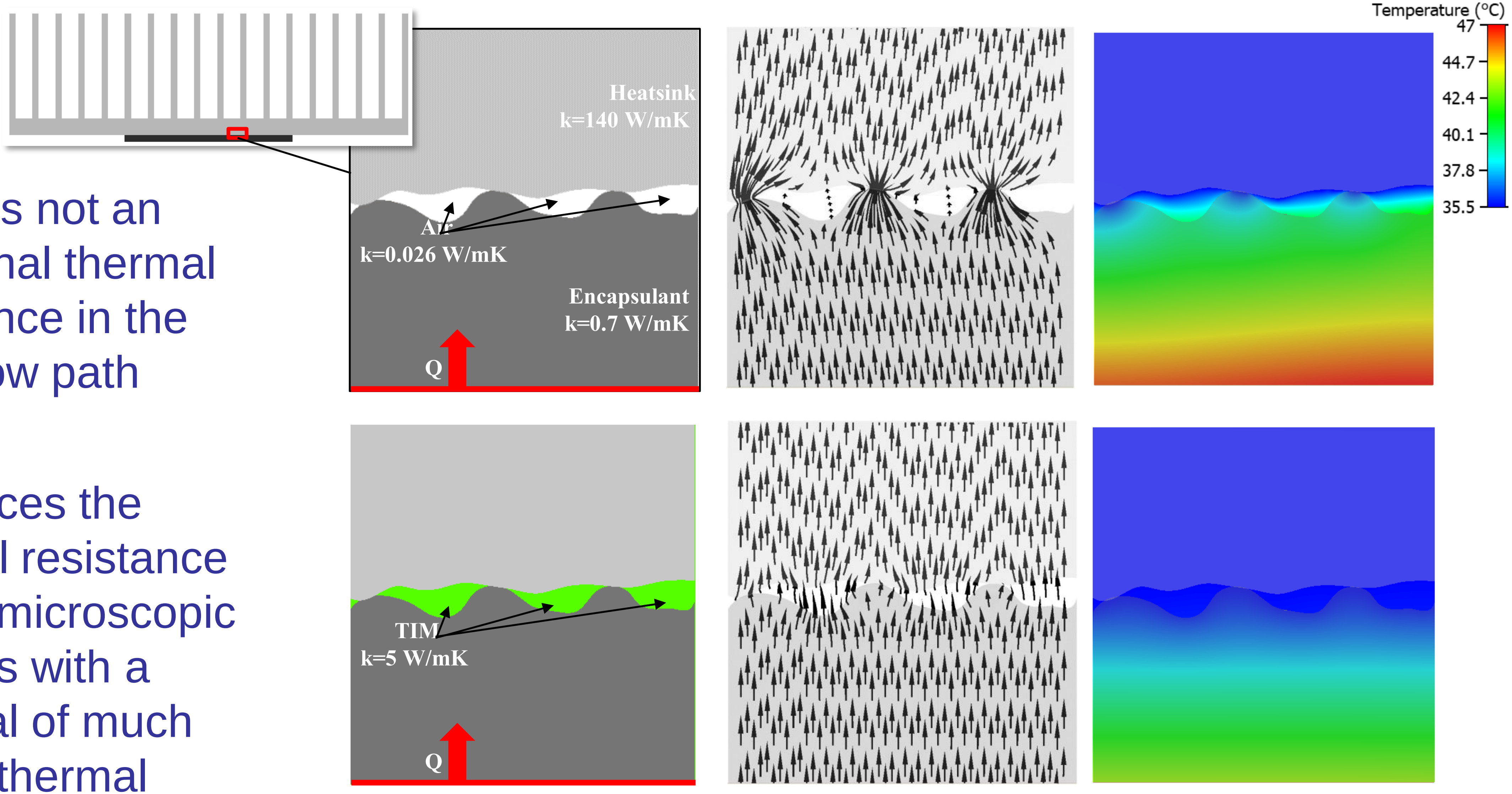
Package structure	L [mm]	W [mm]	H [mm]	V[mm3]	Material	Cth [Ws/K]
Chip	4	3	0.3	3.6	Si	**5.75E-03**
Die attach	4	3	?	?	?	**~2.00E-3**
Heat spreader	9.5	5.6	1.3	69.16	Cu	**2.35E-01**
Cooling flag + TIM	10.4	6.5	1.3	87.88	Cu	**2.98E-01**



The Benefit of a Thermal Interface Material (TIM)

- A TIM is not an additional thermal resistance in the heat flow path

- It replaces the thermal resistance due to microscopic air gaps with a material of much higher thermal conductivity



Case Study

Effect of TIM materials on thermal performance

Description of the experiment

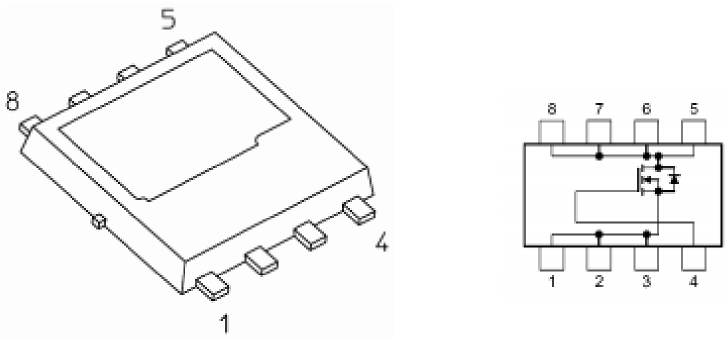
- We used a test board aimed at motor drive and control for handheld power tool applications, using their Cu connector technology:

- We tested a set of TIM materials to transfer heat between the top surface of the MOSFETS-s and a heat-sink.
- The thermal performance was tested without any heatsink and with a set of TIM materials:
  - Gap fillers
  - Adhesives
  - Phase change materials

Special thanks to Toshiba Corp. for the test board and Laird Corporation for the TIM materials!

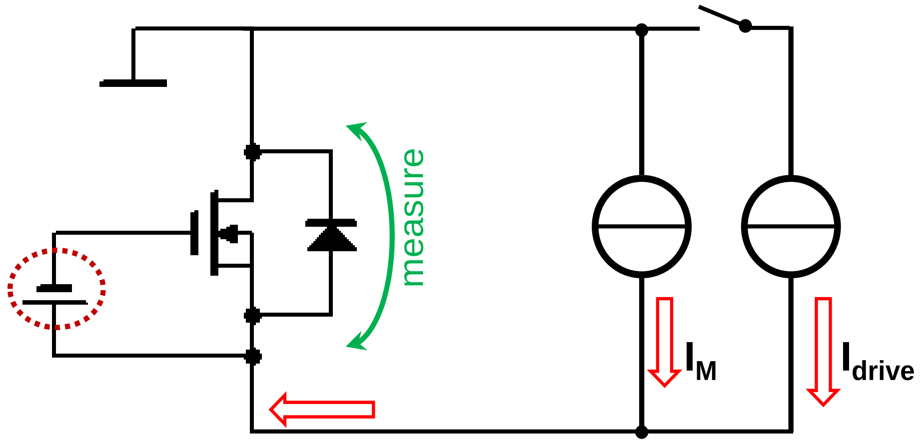
Test Configuration

- We used the MOSFET's (TPWR8004PL) body diode to heat and to sense.
  - Ids_sensing = 200mA
  - Ids_heating = 2A (Air),
    10A (HD350 gap filler),
    15A (HD720, CR350, CR607),
    20A (TPCM5400, TPCM7400)
  - Heating time = 3600s (Air),
    240s (Others)
  - Sensing time = 3600s (Air),
    240s (Others)
  - Cold plate = 25C



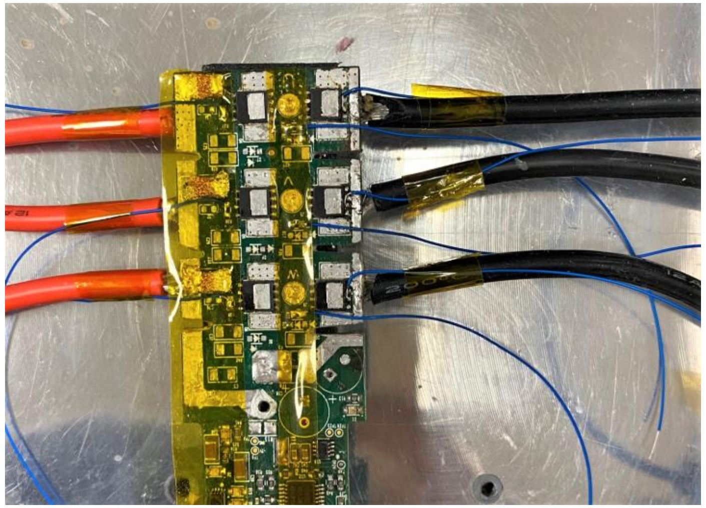
1, 2, 3: Source
4: Gate
5, 6, 7, 8: Drain

DSOP Advance

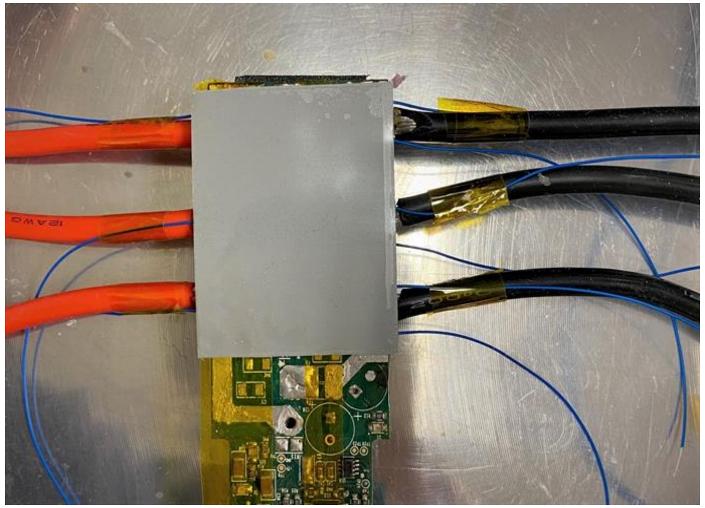


Applied Test Setup

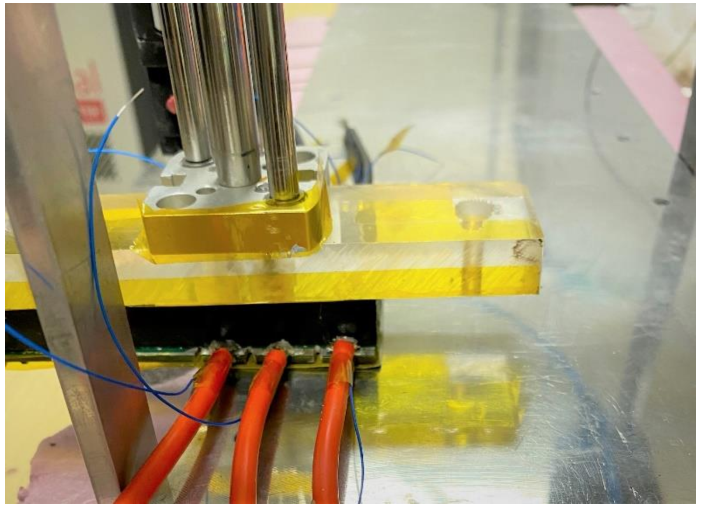
1: Add kapton insulation (1 mil, optional)



2: Apply TIM

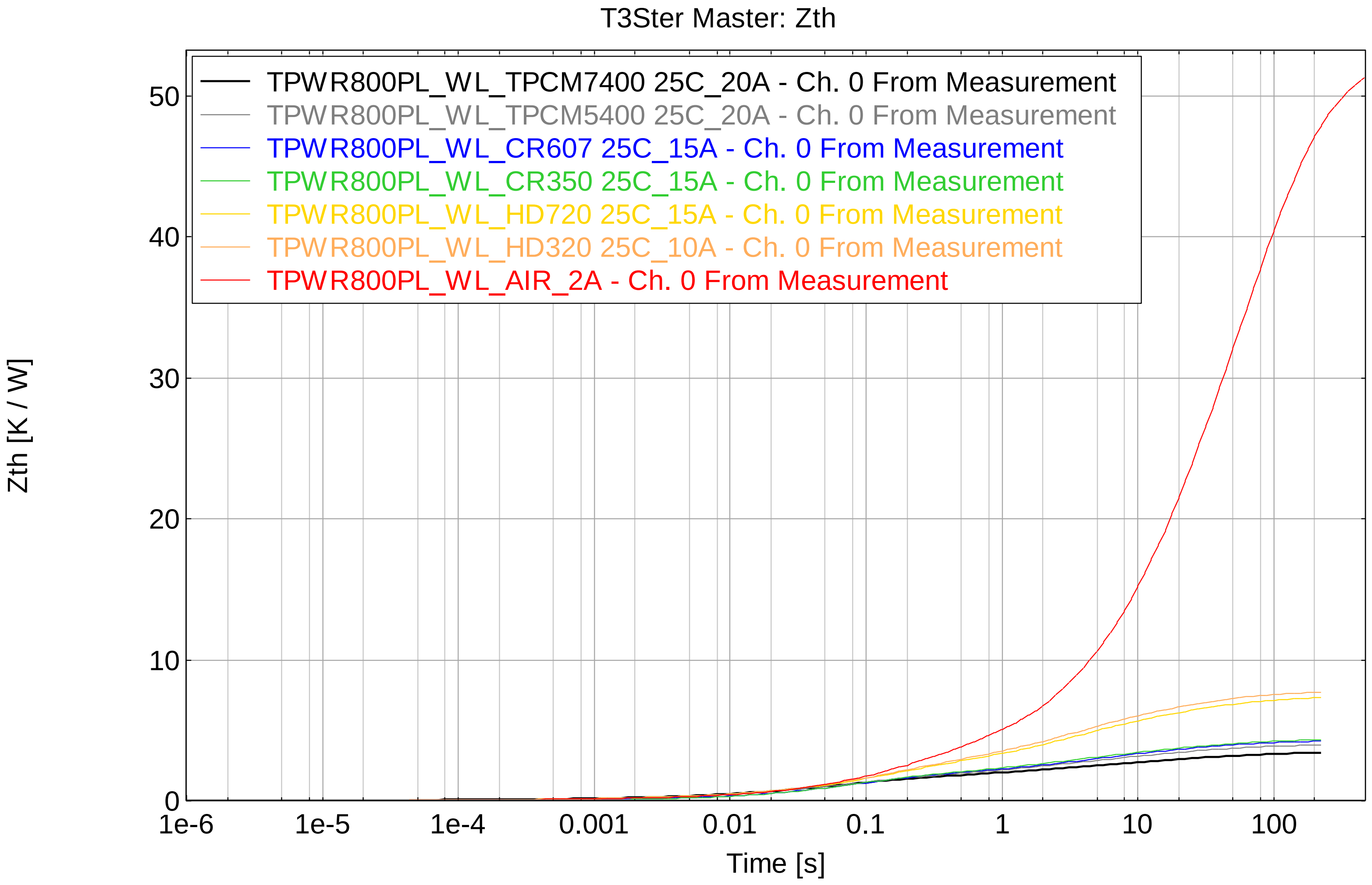


3: Press (30 PSI)



PCMs unser constant pressure can deflect to minimum BLT

Results overview



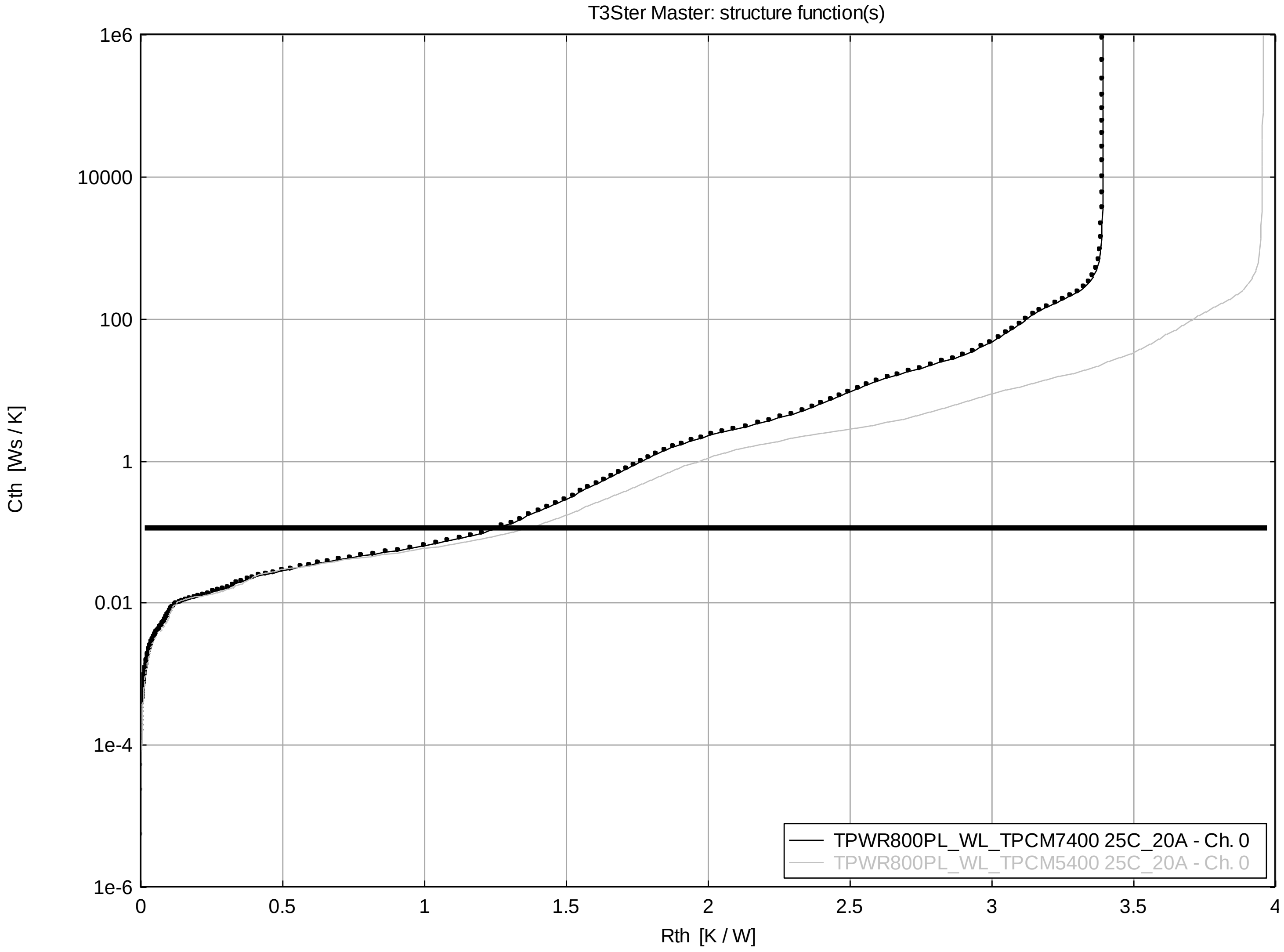
HP TIMs PCMs and Greases

- Used to interface with the most critical components which are generally the hottest.
- The driving force is top thermal performance
- These are thin bondline (>50µm), constant pressure applications

  – CPUs
  – GPUs
  – ASICS
  – Power modules – IGBTs, MOSFET-s

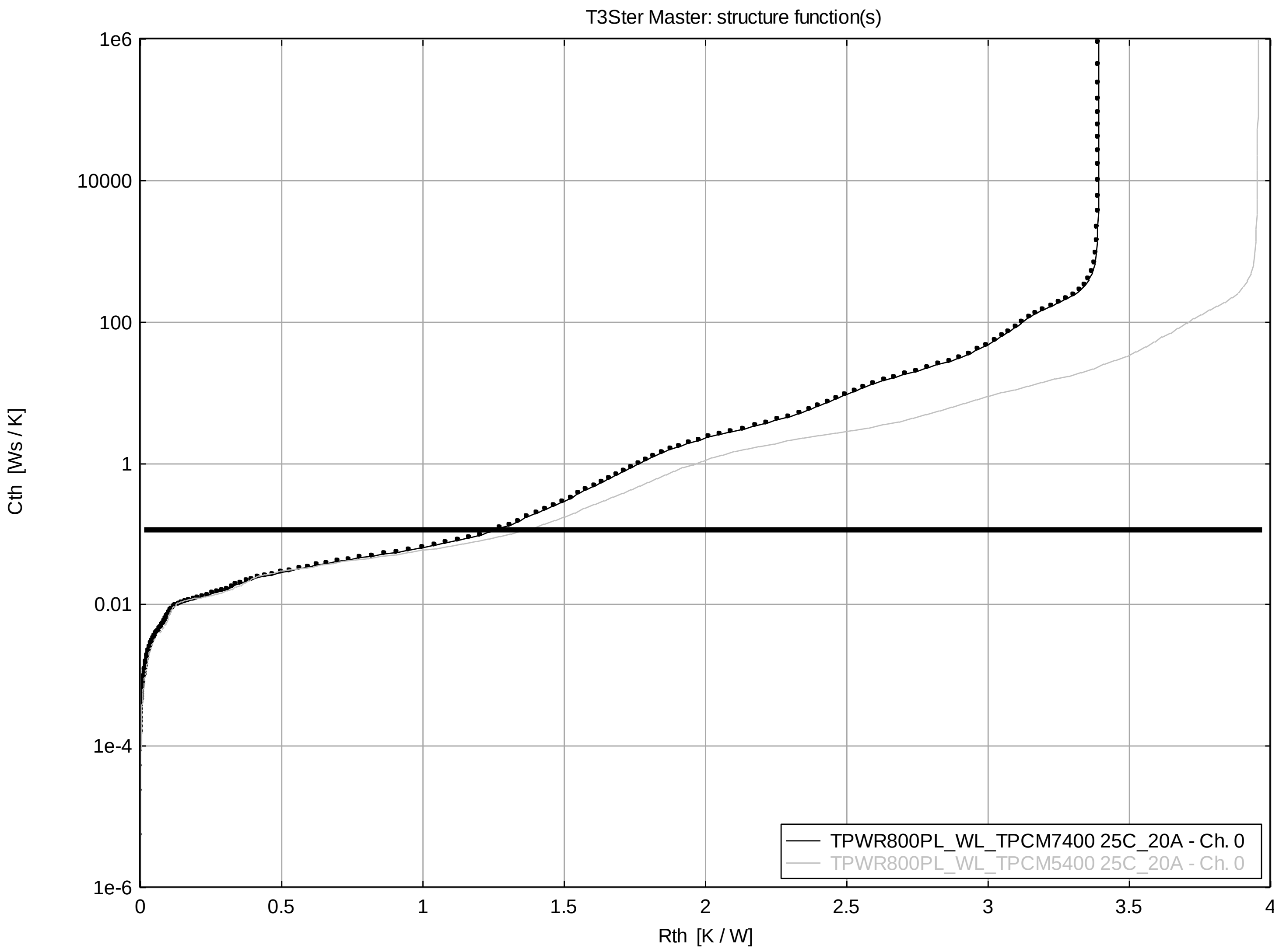
Courtesy of Laird

High Performance Thermal Phase Change Material



	Rth @ 0.1 J/K
TPCM7400	1.213
TPCM5400	1.312

High Performance Thermal Phase Change Material



- **Applications:**
  - **Used to interface with the most critical components which are generally the hottest.**
  - **Thin bondline (>50μm), constant pressure**
- **Properties:**
  - **Soften and flows at transition temperatures**
  - **Minimum interfacial thermal resistance**
  - **Minimizes pump-out**

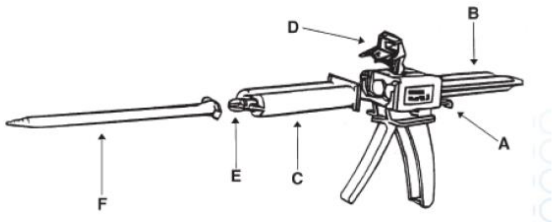
Two-part Liquid Gap Fillers: Cure in place

- Replacing air, filling larger gaps
- Low assembly force
- Better vertical reliability for thicker gaps, resists cracking and bleeding
- Silicone based, part A and part B as duo-cartridges (or pail kits)
  - Mixed through static mixer during dispensing at 1:1 ratio
- Most appreciated by Automotive Industry

Two-part pale system

Duo-cartridges

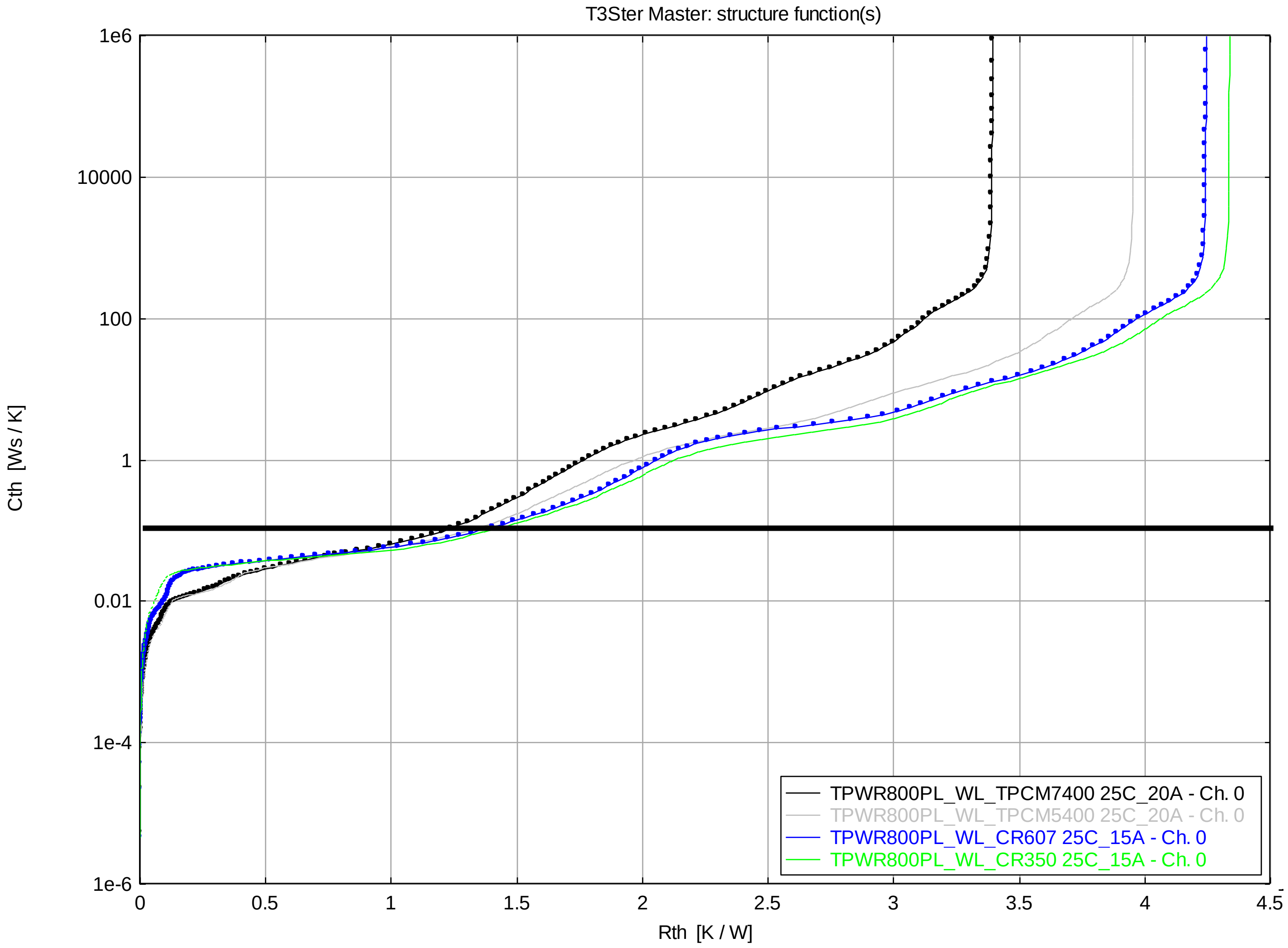
Static mixer

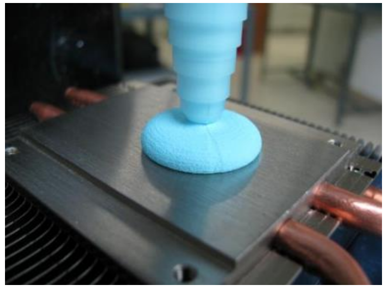


Dispensing gun

Courtesy of Laird

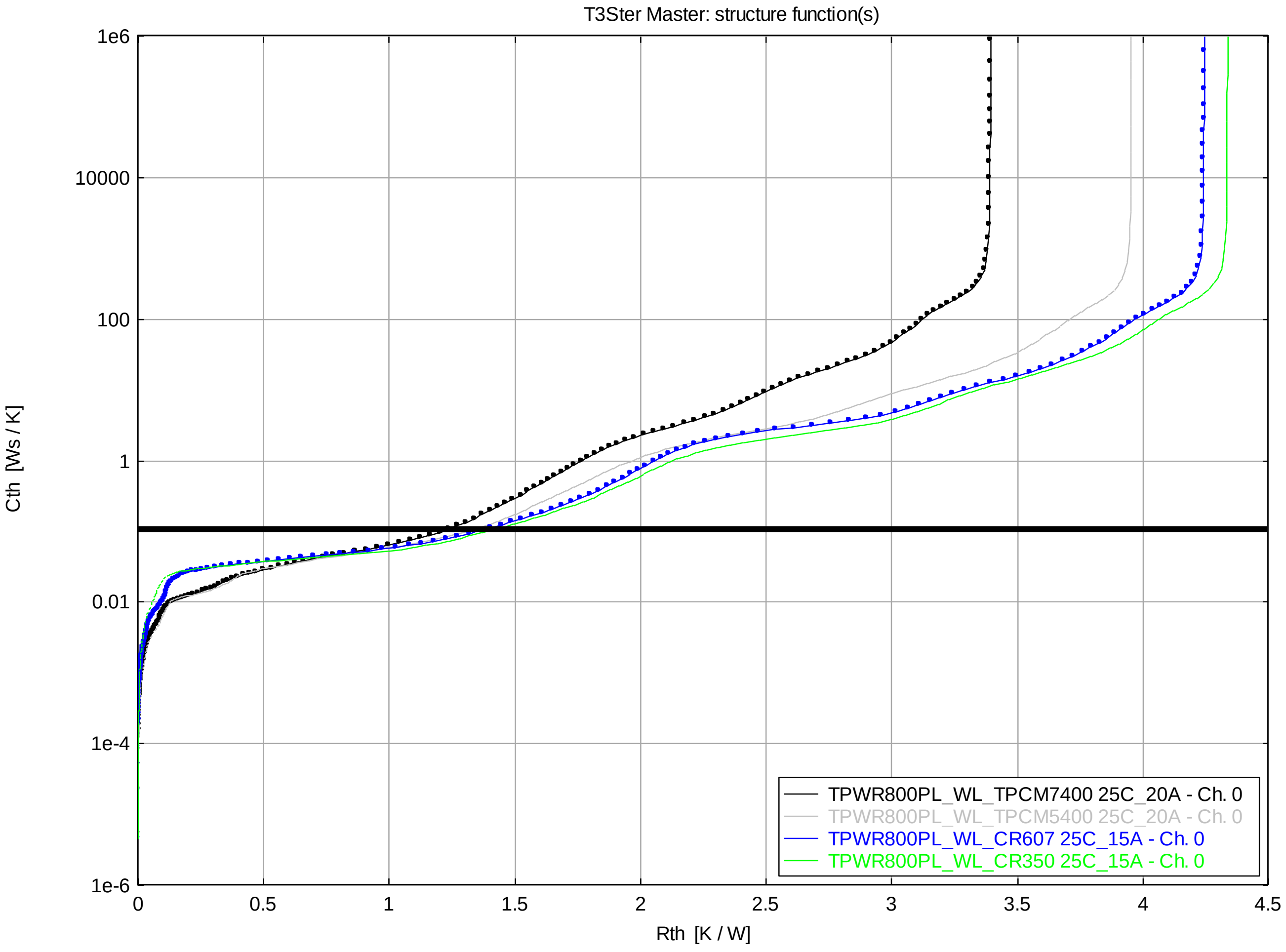
Two Part Liquid Dispensable Gap Filler





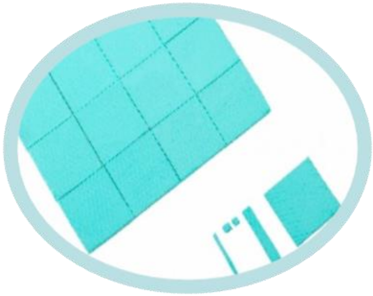
	Rth @ 0.1 J/K
TPCM7400	1.213
TPCM5400	1.312
CR607	1.350
CR350	1.393

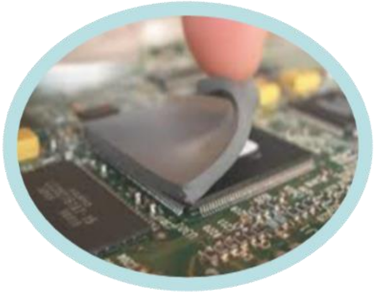
Two Part Liquid Dispensable Gap Filler



- **Applications:**
  - **Meets stringent shock and vibration requirements of the automotive industry**
  - **Fills large gap tolerances**
- **Properties:**
  - **Two part, low thermal resistance**
  - **Soft, minimizes stress during assembly**
  - **High reliability**
  - **Shock absorption**

Gap Fillers TIMs





FEATURES

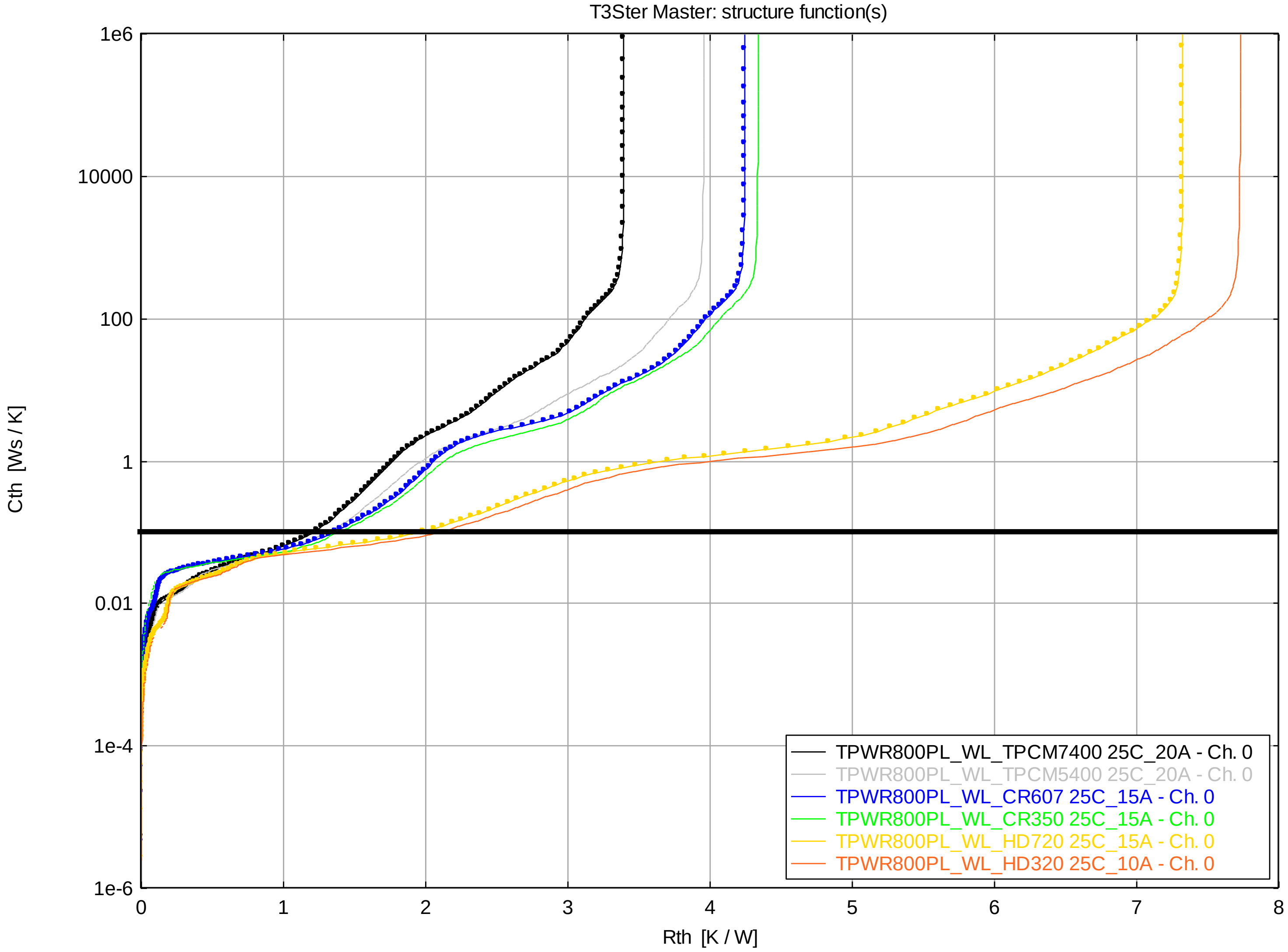
- Thermal Conductivity 1-8 W/mK
- Thickness range 0.008” (0.2mm) to 0.20” (5mm)
- Maintain softness at higher Tc
- Ultra-thin, high deflection, and electrical isolation options
- Naturally tacky materials

BENEFITS

- Softness reduces mechanical stress
- Low pressure vs. deflection
- Low contact resistance increasing overall thermal transfer
- Extend tolerance range of gap

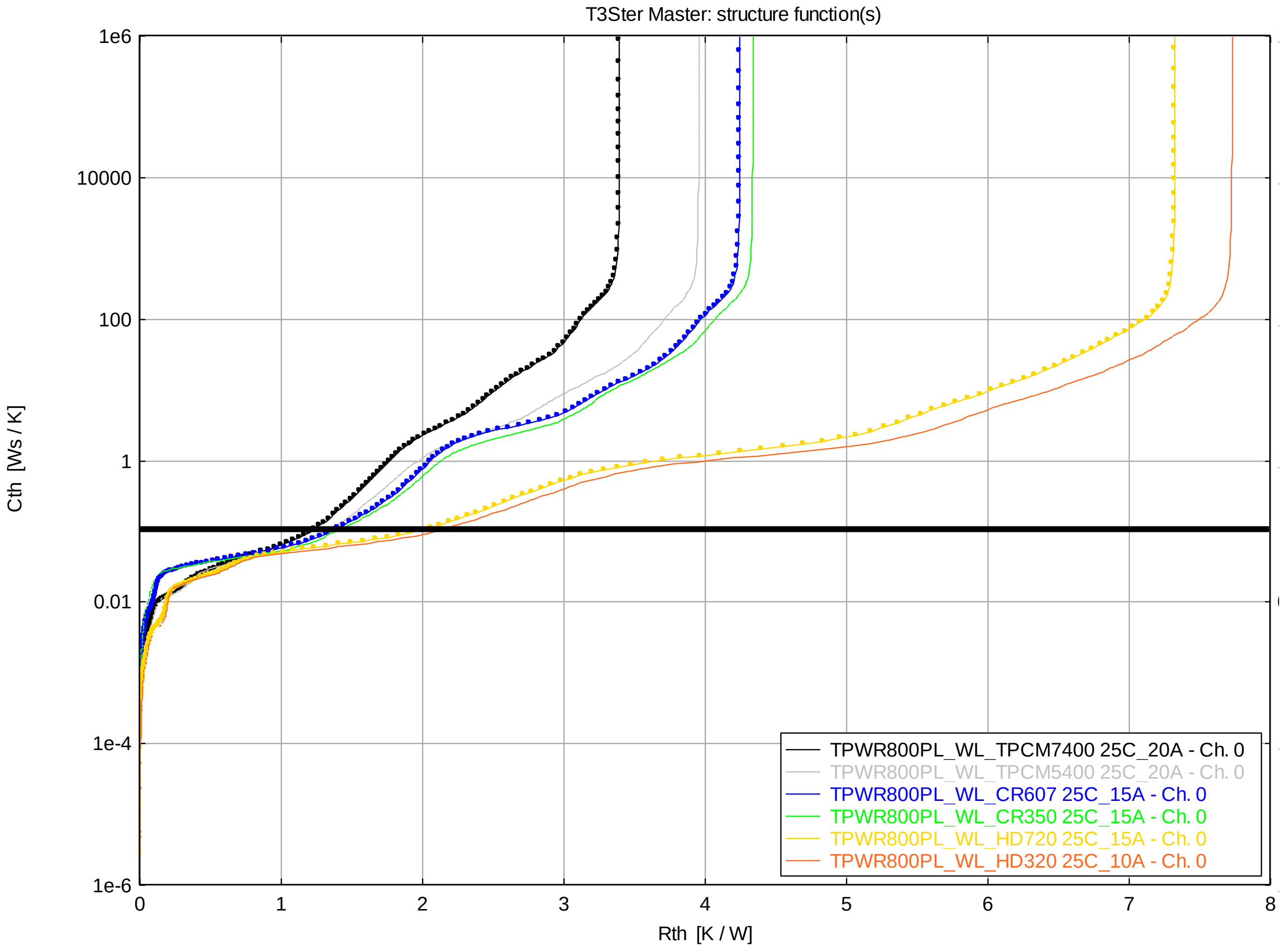
Courtesy of Laird

Silicone based Thermal Gap Filler



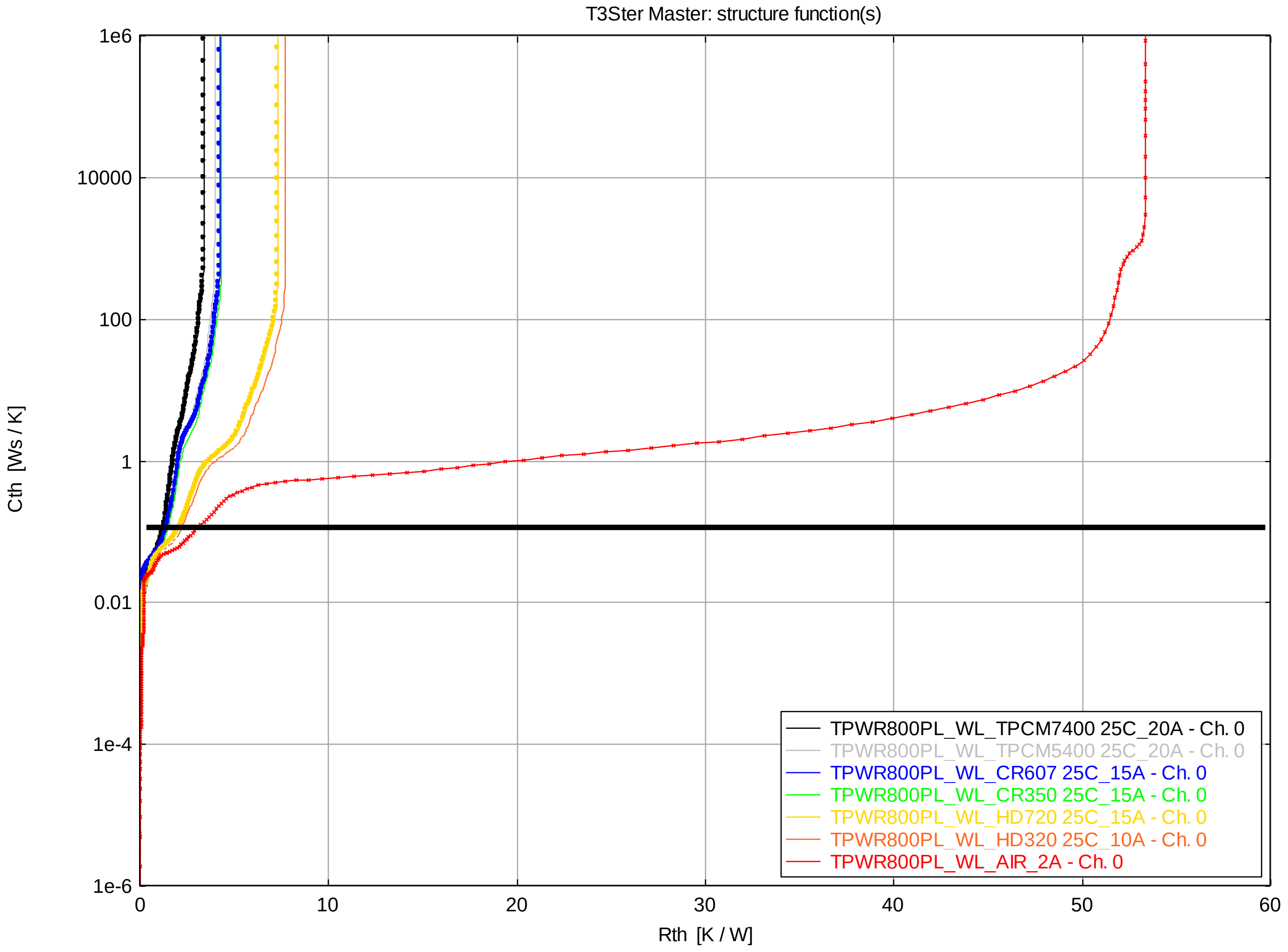
	Rth @ 0.1 J/K
TPCM7400	1.213
TPCM5400	1.312
CR607	1.350
CR350	1.393
HD720	1.956
HD320	2.091

Silicone based Thermal Gap Filler



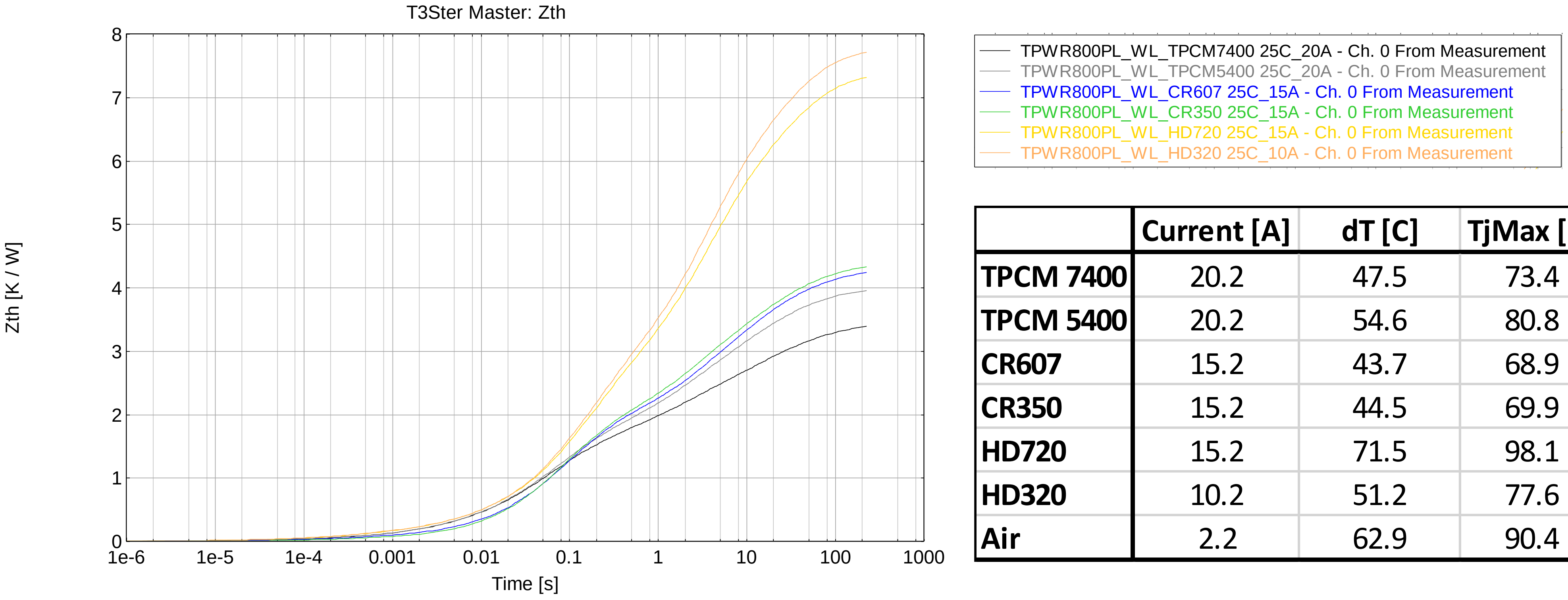
- **Applications:**
  - **Aerospace/defense**
  - **Automotive**
  - **Consumer**
- **Properties:**
  - **High deflection product**
  - **Superior pressure vs. deflection characteristics**
  - **Reduces mechanical stress**
- **Supplied:**
  - **Different thicknesses and multiple converted formats**

All Materials Compared to Having an Airgap Only



	Rth @ 0.1 J/K
TPCM7400	1.213
TPCM5400	1.312
CR607	1.350
CR350	1.393
HD720	1.956
HD320	2.091
AIR	2.840

Result overview and Conclusion



	Current [A]	dT [C]	TjMax [C]	RthJA [K/W]	Power [W]
TPCM 7400	20.2	47.5	73.4	**3.39**	**14.0**
TPCM 5400	20.2	54.6	80.8	**3.95**	**13.8**
CR607	15.2	43.7	68.9	**4.23**	**10.3**
CR350	15.2	44.5	69.9	**4.32**	**10.3**
HD720	15.2	71.5	98.1	**7.31**	**9.8**
HD320	10.2	51.2	77.6	**7.71**	**6.6**
Air	2.2	62.9	90.4	**52.90**	**1.2**