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Challenges faced for TIM Selection for Production Testing & Packaging

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Agenda

- ❖ Introduction
- ❖ Considerations on selecting TIMs
- ❖ TIM's Applications in Semiconductor Industry
- ❖ Thermal Comparison for different TIM materials
- ❖ Thermal Comparison for TIM material with and without adhesives
- ❖ Thermal Validation for TIM subjected to elevated temperature(270°C)
- ❖ Conclusion

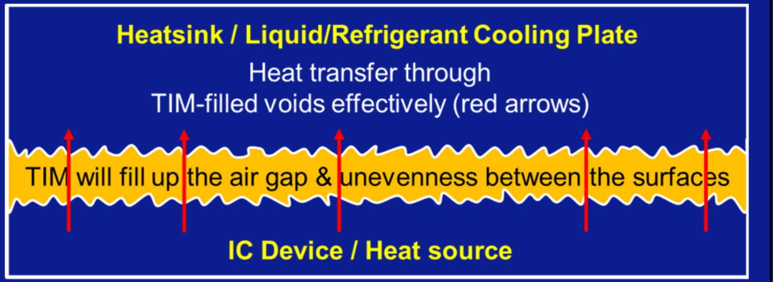
Introduction

- As technology evolved over the last decade, form factors of devices are getting smaller, however the demand for faster speed & higher performance are expected.
- This result to more heat generated due to fast switching of integrated circuits (ICs) and power electronics.
- TIM is critical in determining the time-response on the heat/cool transfer rate between the IC device and thermal head during the test process.
- This paper provides an overall view of the challenges of choosing a suitable adhesive-coated thermal interface material.
- It also describes the advantages versus disadvantages of various materials which are key essential to optimize the performance for solving thermal issues.

Considerations on selecting TIM

- Heat transfer between 2 hard surfaces may not be good
  - ✓ There are no perfect, smooth surfaces
  - ✓ Hard TIM has lesser surface compliance than soft TIM

- Characteristic of TIM Type
  - ✓ Thermal conductivity may not be representative in actual applications
  - ✓ Understand the compression ratio for each material
  - ✓ For silicone-based TIM, the bond will weaken when the volume of thermal filler increases
  - ✓ Select correct thickness for your applications.
    - Thickness is more critical for clamshell-type testing.
    - Thickness & size limitation for different TIM
  - ✓ Know the temperature specs for each material

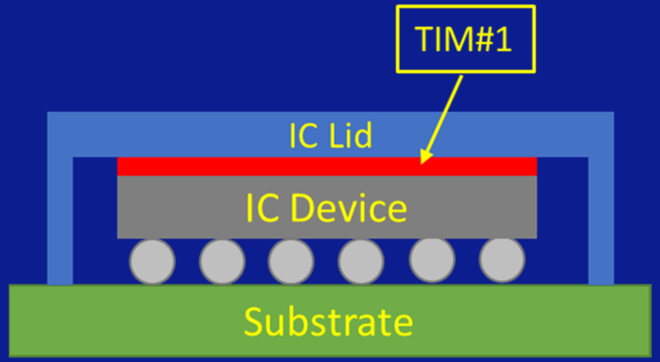


Considerations on selecting TIM

- Understanding the mechanics
  - ✓ Warpage of device/module before and after compression
  - ✓ Surface roughness
  - ✓ Compression force & direction
  - ✓ Tilt & gimballing of pedestal/thermal head
- Visual mechanical issues from repeated cycling
  - ✓ Particle drop-off
  - ✓ TIM migration causing contamination/stain
- Adding adhesive to TIM will result in big degradation in thermal performance
  - ✓ Adhesive is a poor conductor of heat
  - ✓ What are the options available?

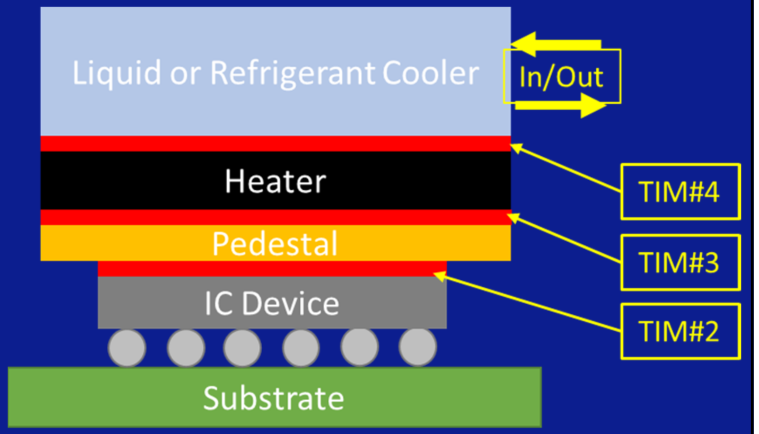
TIM's Applications in Semiconductor

❖ Application for TIM #1
- ✓ Application:
  - One-Time-Use
  - For example, encapsulated inside of devices
- ✓ Challenges:
  - Application / installation during production
  - Components shorting after encapsulation
  - Particles drop-out / pump-out
  - Dry-out for liquid type material
  - Degradation of performance after multiple reflow



TIM's Applications in Semiconductor

- Application for TIM #2, #3, #4
  - ✓ Application:
    - Repeat-Cycling
    - For example, Final Test, System Level, Burn-In
  - ✓ Challenges:
    - Attachment methods
      - Adhesive on material
      - Mechanical method
    - Particles drop-out during repeat compression
    - Stain / Contamination
    - Thermal performance compromised with adhesive
    - Material shift after repeat compression due to mechanical design



Thermal Evaluation Set-Up

❖ **Test Station**

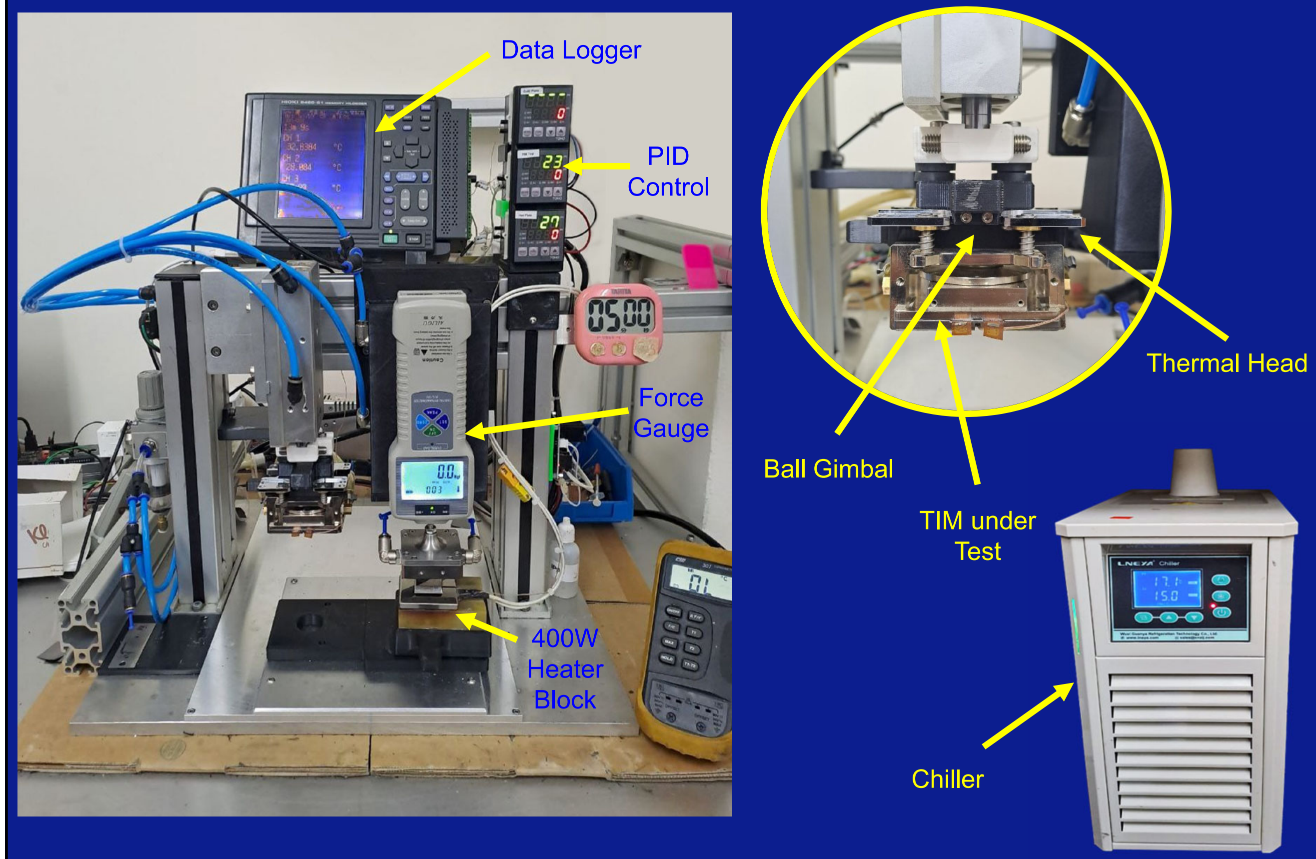
An in-house designed test station was built to validate the performance of different TIMs based on the following:

- ✓ Ramp-Up
  - To determine the speed the TIM is able to suppress the temperature, using a chiller operating at fixed temperature
  - The TIM's efficiency is good if it is lower on the curve
- ✓ Ramp-Down
  - To determine the rate of temperature drop for the TIM
  - The TIM's efficiency is good if it is lower on the curve

❖ **Test Procedure**

- ✓ Ramp-Up
  - The heater power will be at 100% at 400W, and chiller temperature is fixed at 15°C
  - When temperature is measured at 30 °C, the cylinder will come down at 40psi to be in contact with the heat source & TIM.
  - The data logger will track the temperature at 1 sec interval over 2 mins.
- ✓ Ramp-Down
  - The temperature for the heat source will be controlled at 125°C
  - The power of the heat source will be cut off once the cylinder moves the cooler in contact with the heat source & TIM.
  - The data logger will track the temperature at 1 sec interval over 2 mins.

Thermal Evaluation Set-Up



Set-Up Parameters

- **Chiller**
  - ✓ Temperature: 15°C
  - ✓ Flowrate : 10L/min
- **Cylinder**
  - ✓ Pressure : 40psi
- **TIM Sample**
  - ✓ Size : 25.4 X 25.4 (mm)
- **Comments**
  - ✓ All parameters are fixed for the whole experiment, the only variable is the change of TIM materials

DOE’s Objectives

DOE #1

- To carry out a thermal comparison for different thermal interface materials.

DOE #2

- To carry out a thermal comparison of different adhesives coated on graphite material. This will be compared against the uncoated graphite material.

DOE #3

- To study the thermal effect of adhesive-coated graphite TIM, when subjected to 2 times of elevated temperature (soak at 270°C for 5mins).

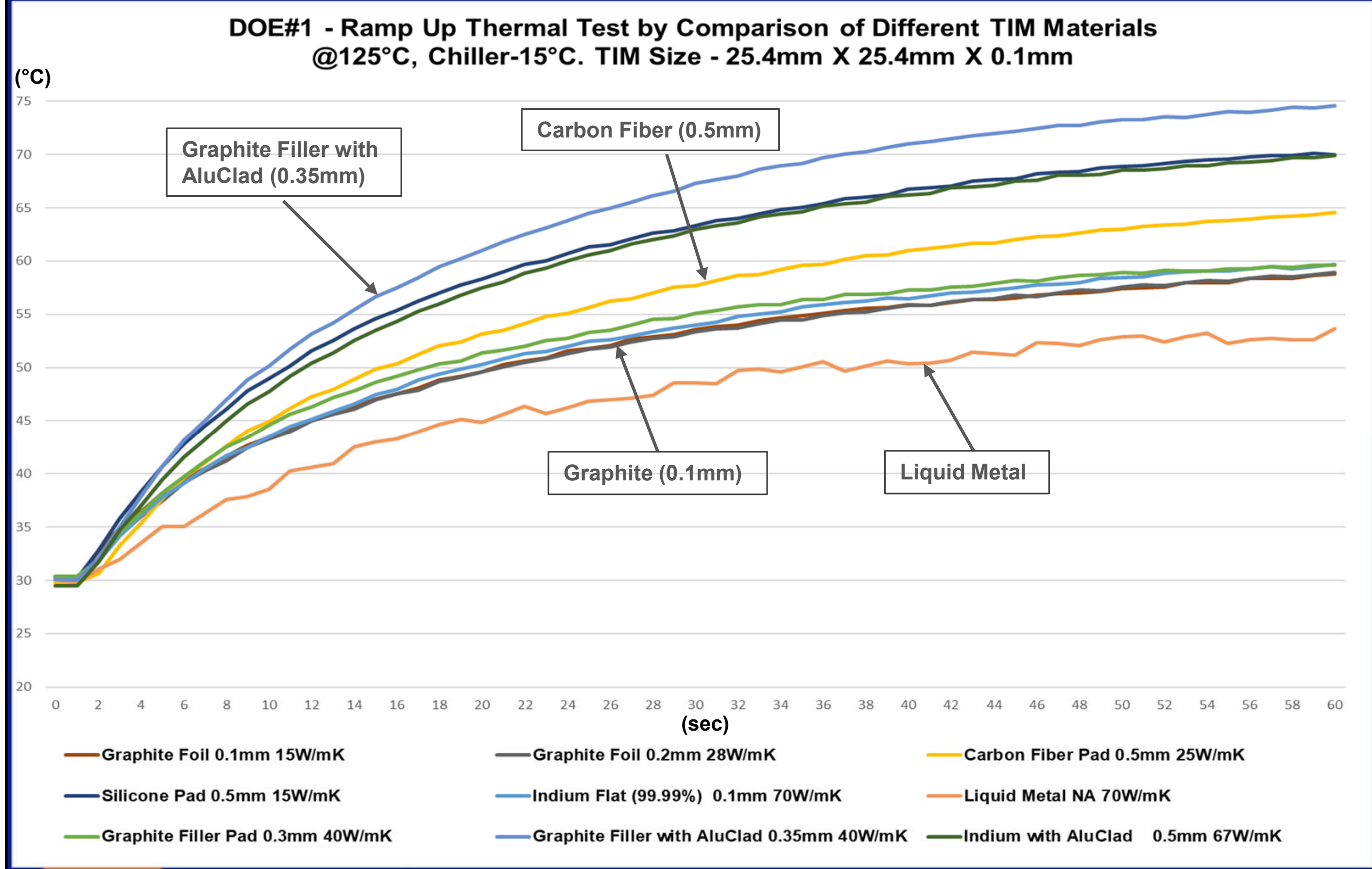
*Note
All adhesives (eg LTPSA, HTPSA, TSA, GA288) in this experiment are proprietary products developed by Inspiraz, and are used in the DOEs to run the validation.
(LTPSA – Pressure sensitive adhesive, HTPSA – Enhanced Strength pressure sensitive adhesive, TSA – Temperature sensitive adhesive, GA288 – Carbon-based liquid adhesive)

DOE #1 - Setup

- **Objective**
  - ✓ To carry out a thermal comparison for different thermal interface materials
- **Test Method**
  - ✓ A ramp-up & ramp-down testing method is used to validate the response and rate of transfer of the cooler to the heat source, via the TIM material
- **Outcome**
  - ✓ The TIMs exhibiting lower temperature on the graph imply a good interfacial surface resulting in good heat transfer from cool plate to the heat source

Material Type	Thickness (mm)	Thermal Conductivity (W/mK)
Graphite	0.1	15
Silicone Thermal Pad	0.4	15
Carbon Fiber Pad	0.5	25
Indium (99.99%)	0.1	70
Indium with AluClad	0.35	67
Graphite Fillers Pad	0.3	40
Graphite Fillers with AluClad	0.35	40
Liquid Metal	NA	70

DOE #1 – Ramp Up Test Results



Ranking by Performance

Rank	Part Number	Material Type	Thickness (mm)
1	LVM-700	Liquid Metal	NA
2	TCGS-100	Graphite	0.2
3	TCGS-220	Graphite	0.1
4	PCM-500	Indium - Flat	0.1
5	Product 'A'	Graphite Filler	0.3
6	CTP-300	Carbon Fiber	0.5
7	Product 'C'	Indium with AluClad	0.35
8	STP-400	Silicone Pad	0.5
9	Product 'B'	Graphite Fillers with AluClad	0.35

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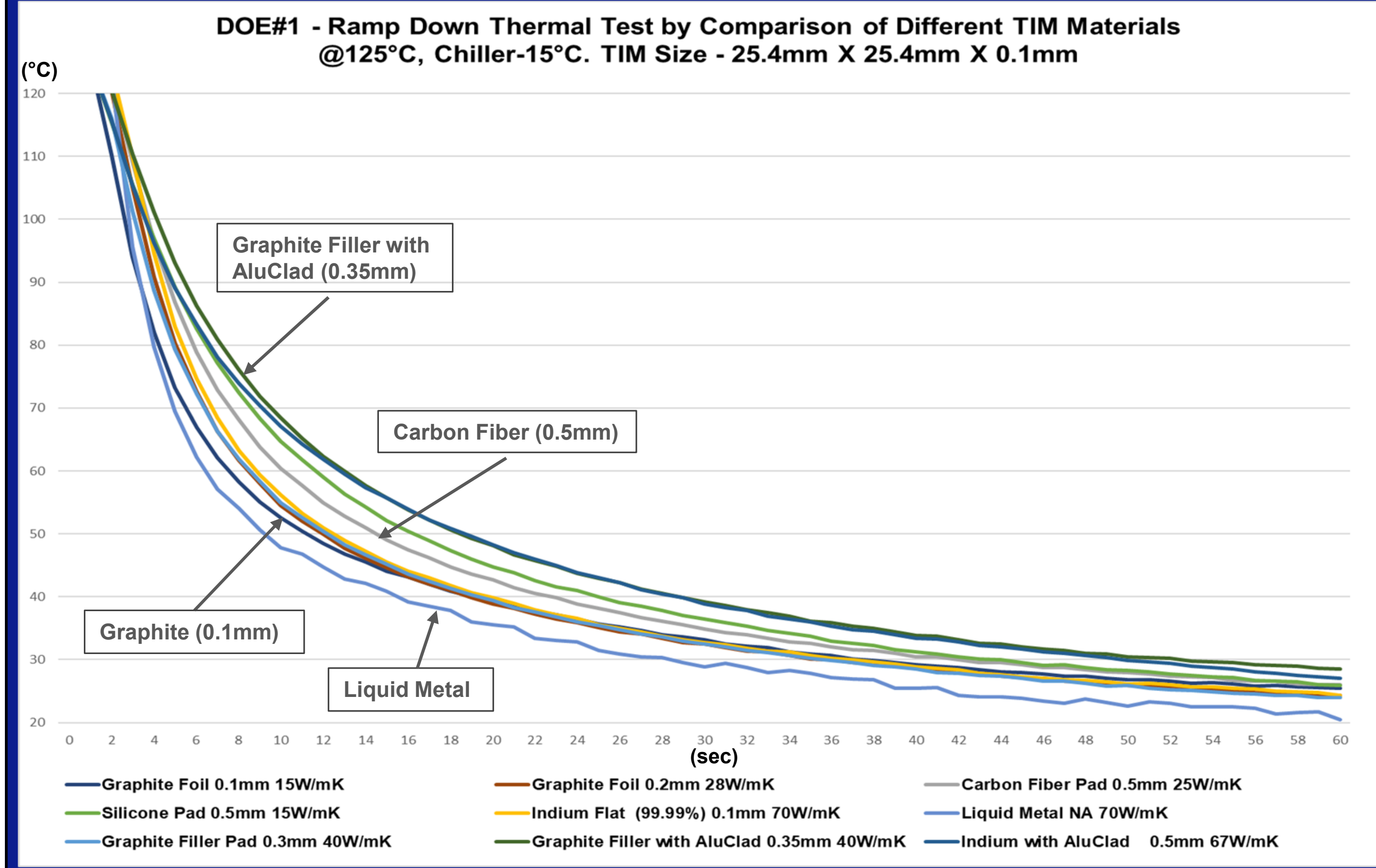
DOE #1 – Ramp Down Test Results



Ranking by Performance

Rank	Part Number	Material Type	Thickness (mm)
1	LVM-700	Liquid Metal	NA
2	TCGS-220	Graphite	0.1
3	TCGS-100	Graphite	0.2
4	Product 'A'	Graphite Filler	0.3
5	PCM-500	Indium - Flat	0.1
6	CTP-300	Carbon Fiber	0.5
7	STP-400	Silicone Pad	0.5
8	Product 'C'	Indium with AluClad	0.35
9	Product 'B'	Graphite Filler with AluClad	0.35

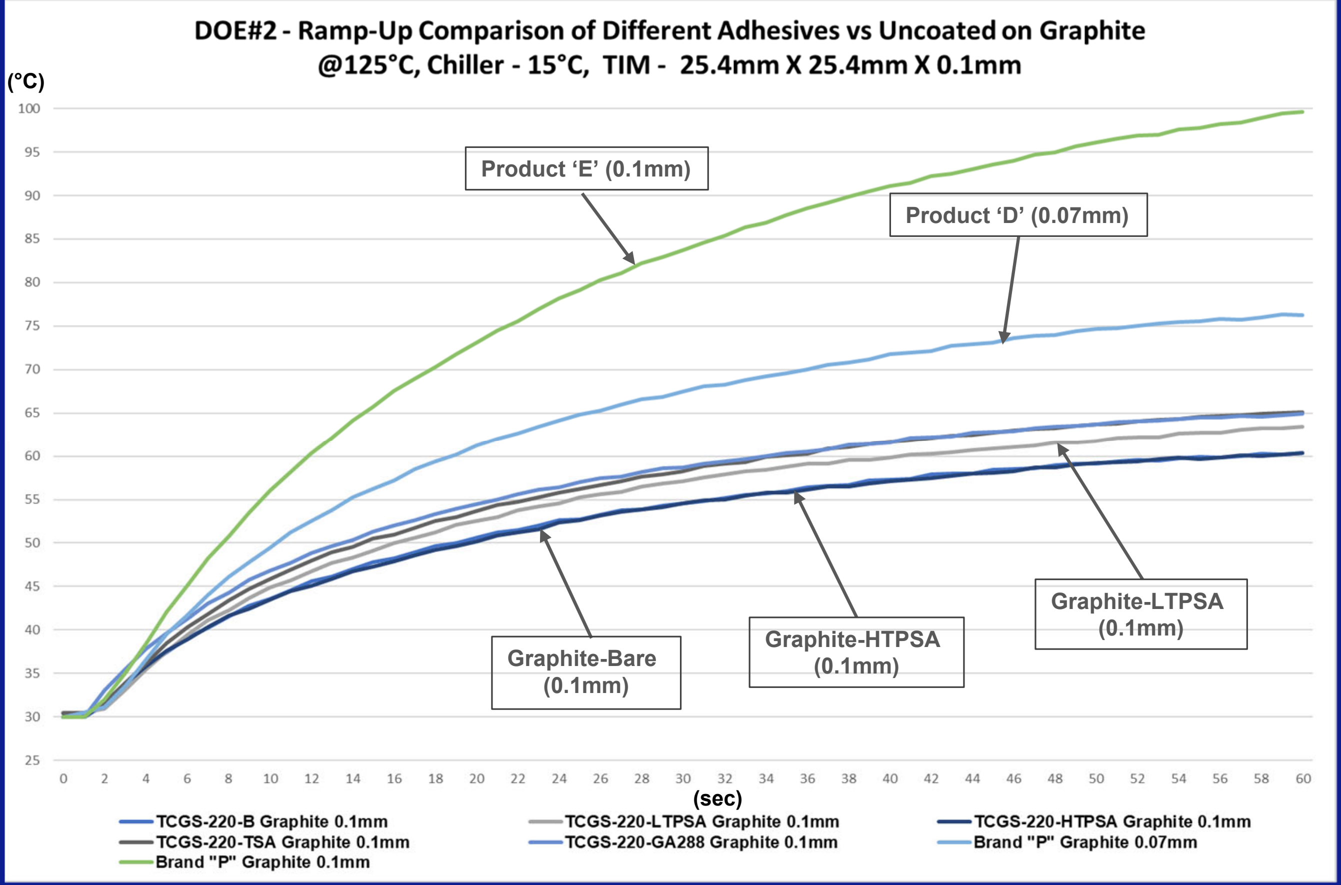
DOE #1 - Findings

- Liquid Metal TIM performs the best
- TIM material with lower thermal conductivity may perform better than that with higher thermal conductivity, eg graphite (15W/mK) vs PCM (70W/mK)
- Thicker TIM material may perform better than thinner TIM material, eg graphite filler (0.3mm) vs PCM (0.1mm)
- While the thermal conductivity of aluminium range from 88 to 250W/mK, the addition of Alu foil to TIM is causing a drop in thermal performance. For example, the graphite filler by itself is performing much better than the same material with the Alu foil.

DOE #2

- **Objective**
  - ✓ To carry out a thermal comparison of different adhesives coated on graphite (0.07mm/0.1mm). This will be compared against the uncoated graphite material
- **Material Samples**
  - ✓ Graphite (In-house) – no adhesive, different adhesives, ie LTPSA, HTPSA, TSA, GA288
  - ✓ Brand “P” – embedded adhesive of 2 different thickness (0.07mm & 0.1mm)
- **Test Method**
  - ✓ A ramp-up & ramp-down testing method is used to validate the response and rate of transfer of the cooler to the heat source via the TIM material
- **Outcome**
  - ✓ The TIMs exhibiting lower temperature on the graph imply a good interfacial surface resulting in good heat transfer from cool plate to the heat source

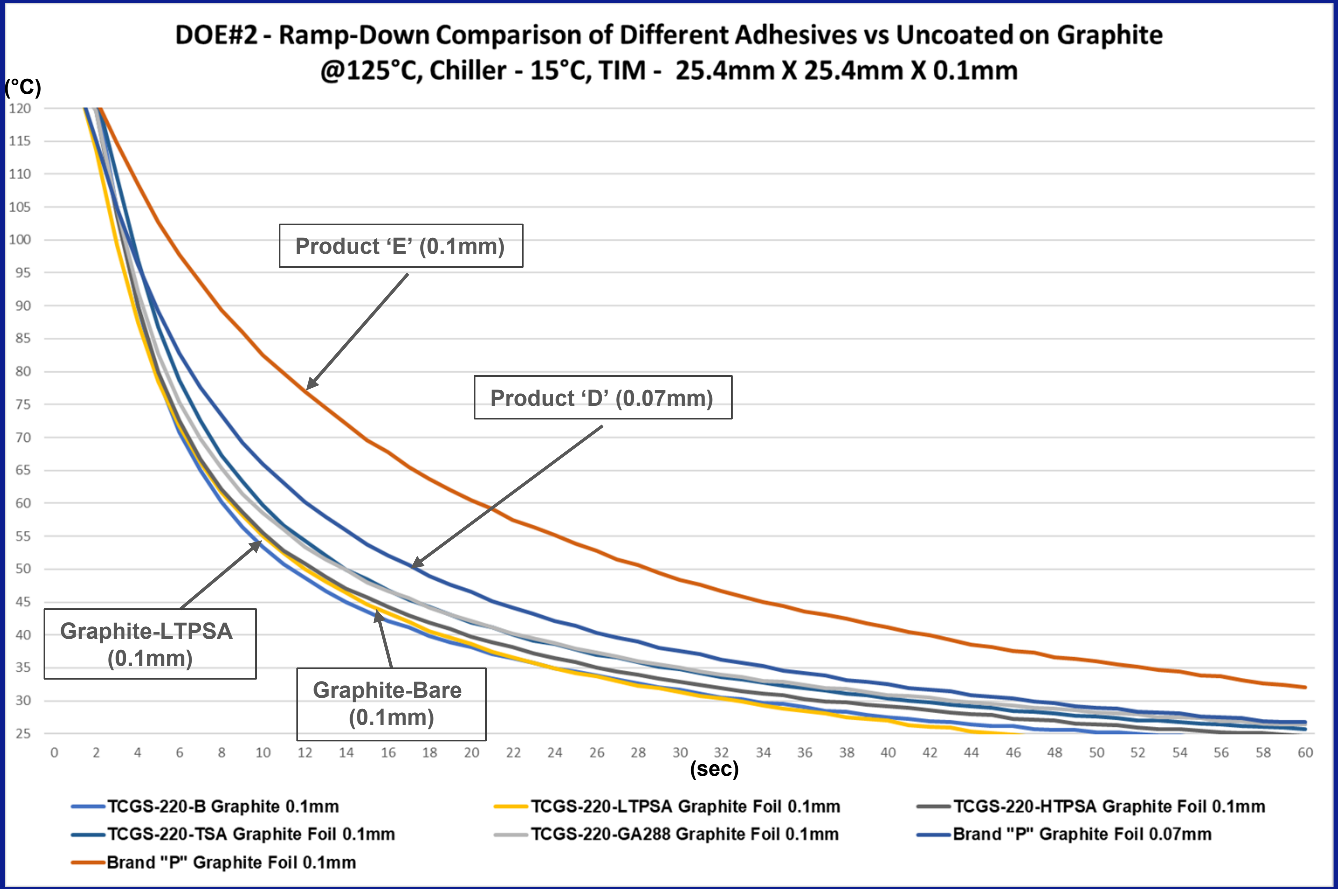
DOE #2 – Ramp Up Test Results



Ranking by Performance

Rank	Part Number	Adhesive	Thickness (mm)
1	TCGS-220	Bare	0.1
2	TCGS-220	HTPSA	0.1
3	TCGS-220	LTPSA	0.1
4	TCGS-220	TSA	0.1
5	TCGS-220	GA288	0.1
6	Product 'D'	Tape	0.07
7	Product 'E'	Tape	0.1

DOE #2 – Ramp-Down Test Results



Ranking by Performance

Rank	Part Number	Adhesive	Thickness (mm)
1	TCGS-220	LTPSA	0.1
2	TCGS-220	Bare	0.1
3	TCGS-220	HTPSA	0.1
4	TCGS-220	GA288	0.1
5	TCGS-220	TSA	0.1
6	Product 'D'	Tape	0.07
7	Product 'E'	Tape	0.1

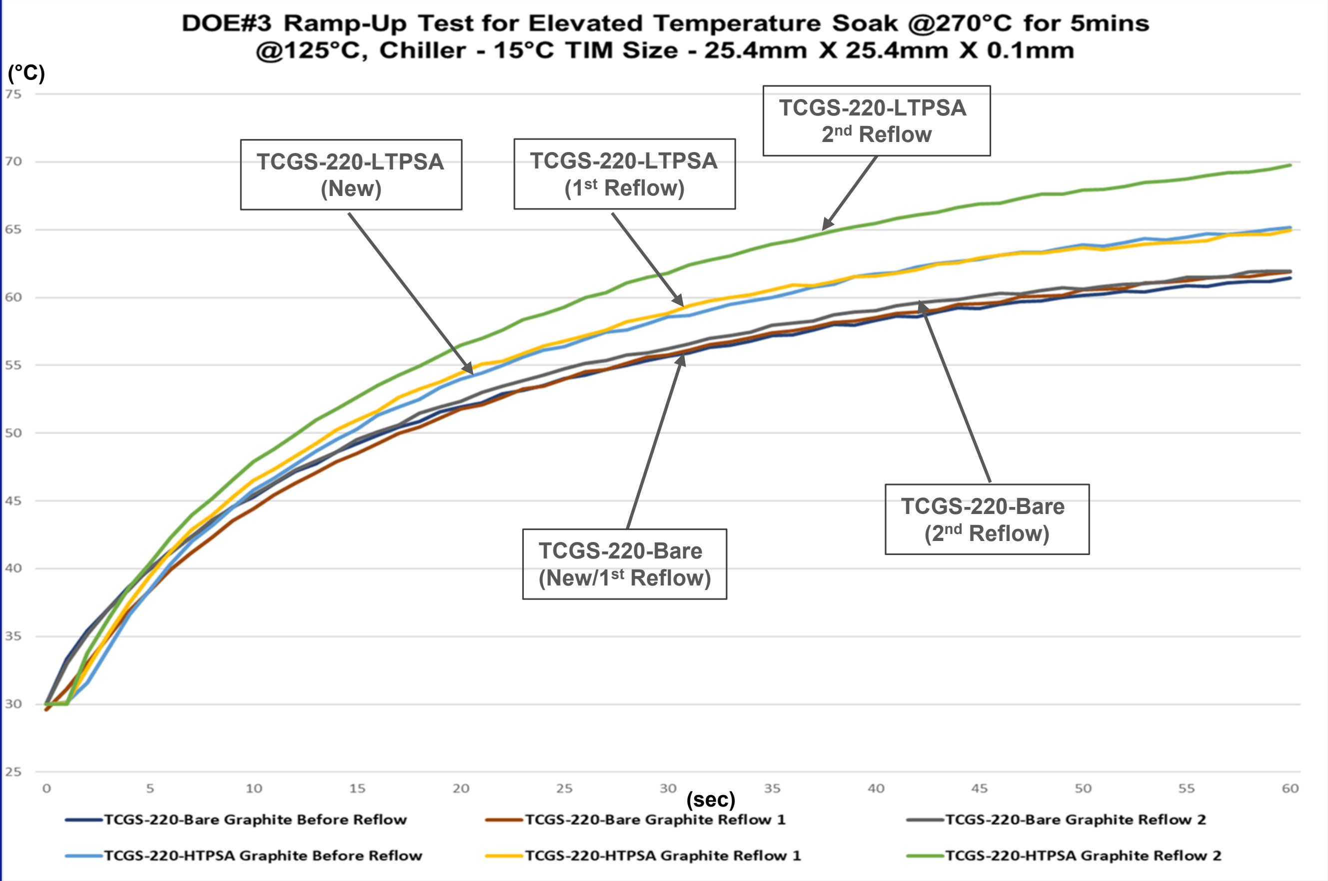
DOE #2 - Findings

- Graphite TIM with LTPSA & HTPSA adhesive has similar performance as the bare uncoated TIM
- Graphite TIM with TSA & GA288 adhesive has a gap of less than 5°C variance from the bare uncoated TIM
- Graphite TIM material with traditional adhesive is performing badly, even for the 0.07mm thick material

DOE #3

- **Objective**
  - To study the physical & thermal effect of adhesive-coated graphite TIM, when subjected to 2 times of elevated temperature (soak at 270°C for 5mins)
- **Material Samples**
  - Bare graphite (0.1mm)
  - Adhesive-coated graphite (0.1mm)
- **Test Method**
  - A ramp-up & ramp-down testing method is used to validate the response and rate of transfer of the cooler to the heat source, via the TIM material
- **Outcome**
  - The TIMs exhibiting lower temperature on the graph imply a good interfacial surface resulting in good heat transfer from cool plate to the heat source

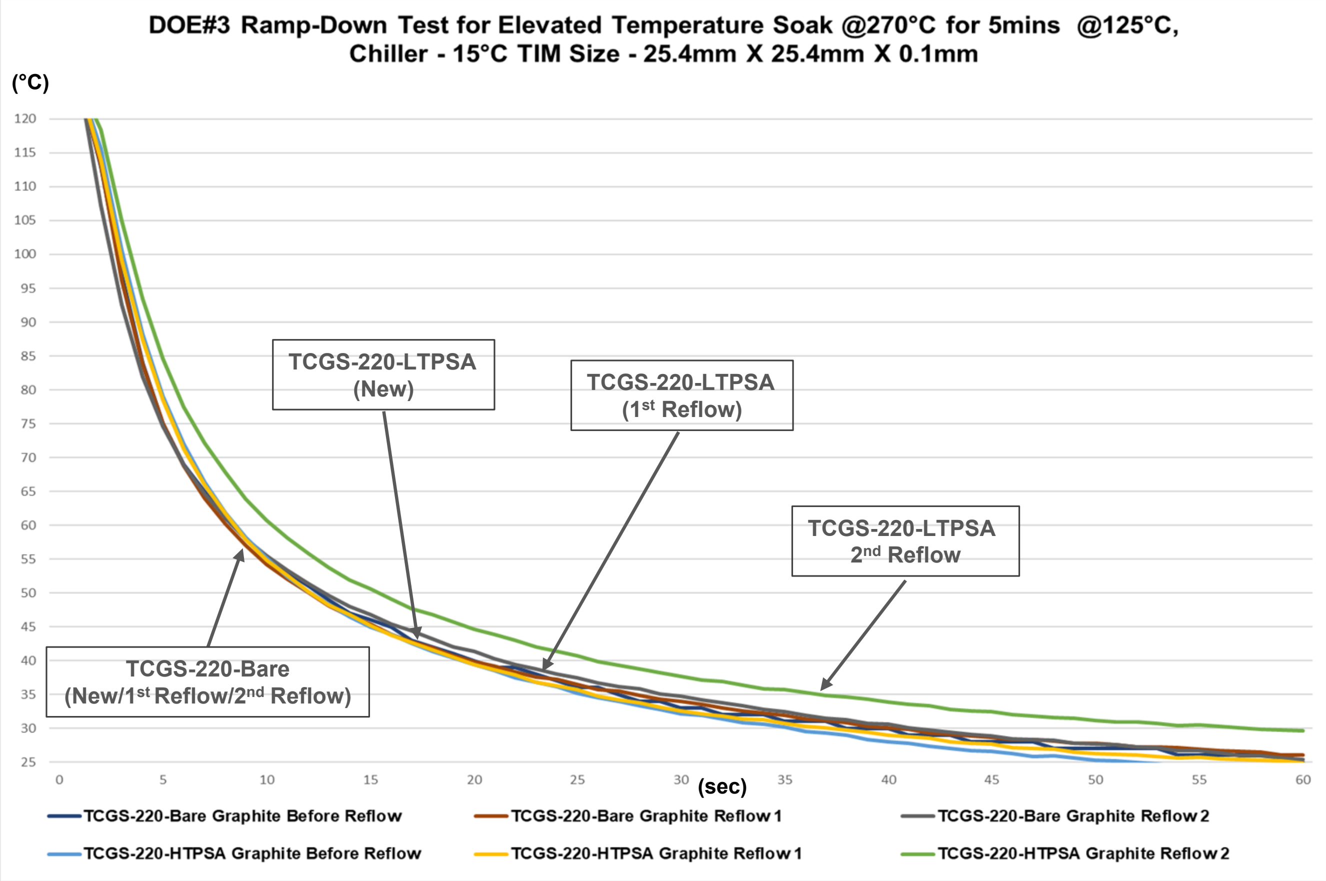
DOE #3 – Ramp Up Test Results



Ranking by Performance

Rank	Part Number	Process
1	TCGS-220-Bare	New
2	TCGS-220-Bare	1st Reflow
3	TCGS-220-Bare	2nd Reflow
4	TCGS-220-LTPSA	New
5	TCGS-220-LTPSA	1st Reflow
6	TCGS-220-LTPSA	2nd Reflow

DOE #3 – Ramp-Down Test Results



Ranking by Performance

Rank	Part Number	Process
1	TCGS-220-Bare	New
2	TCGS-220-Bare	1st Reflow
3	TCGS-220-Bare	2nd Reflow
4	TCGS-220-LTPSA	New
5	TCGS-220-LTPSA	1st Reflow
6	TCGS-220-LTPSA	2nd Reflow

DOE #3 - Findings

- The bare graphite TIM exhibits similar thermal outcome even after going through 2 cycles of reflow simulation at elevated temperature

- The adhesive-coated graphite TIM has a deviation on the thermal performance during the 2 reflow simulation cycles
  - ✓ For Ramp-up
    - The new adhesive-coated TIM has a deviation of 3°C, compared to the bare TIM
    - After 1st reflow, the thermal result is the same as the new material
    - After 2nd reflow, the thermal result increases by 4°C from the new material
  - ✓ For Ramp-down
    - The new adhesive-coated TIM has a deviation of 1°C, compared to the bare TIM
    - After 1st reflow, the thermal result is the same as the new material
    - After 2nd reflow, the thermal result increases by 3°C from the new material

- The adhesive-coated graphite is performing considerably well , even at 270°C , and can be a good candidate for TIM#1 applications.

Conclusion

- Choosing the right TIM, with good compliance between the surfaces will help to improve the thermal response & efficiency
- Thermal conductivity is only an indicator, but may not be the key consideration in the TIM selection. There are other factors that may be more critical to determine the outcome
- TIM using the same material & specifications, but from different manufacturers may have different thermal outcome when used in actual application.
- TIM material with lower thermal conductivity may perform better in actual applications
- It is possible to have adhesive-coated TIM having similar thermal performance as the bare material
- Different TIMs has its own pros & cons -- > choose the right match to the specific applications