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The effect of surface roughness on the thermal performance of vertically aligned graphene enhanced and polymer based thermal interface material

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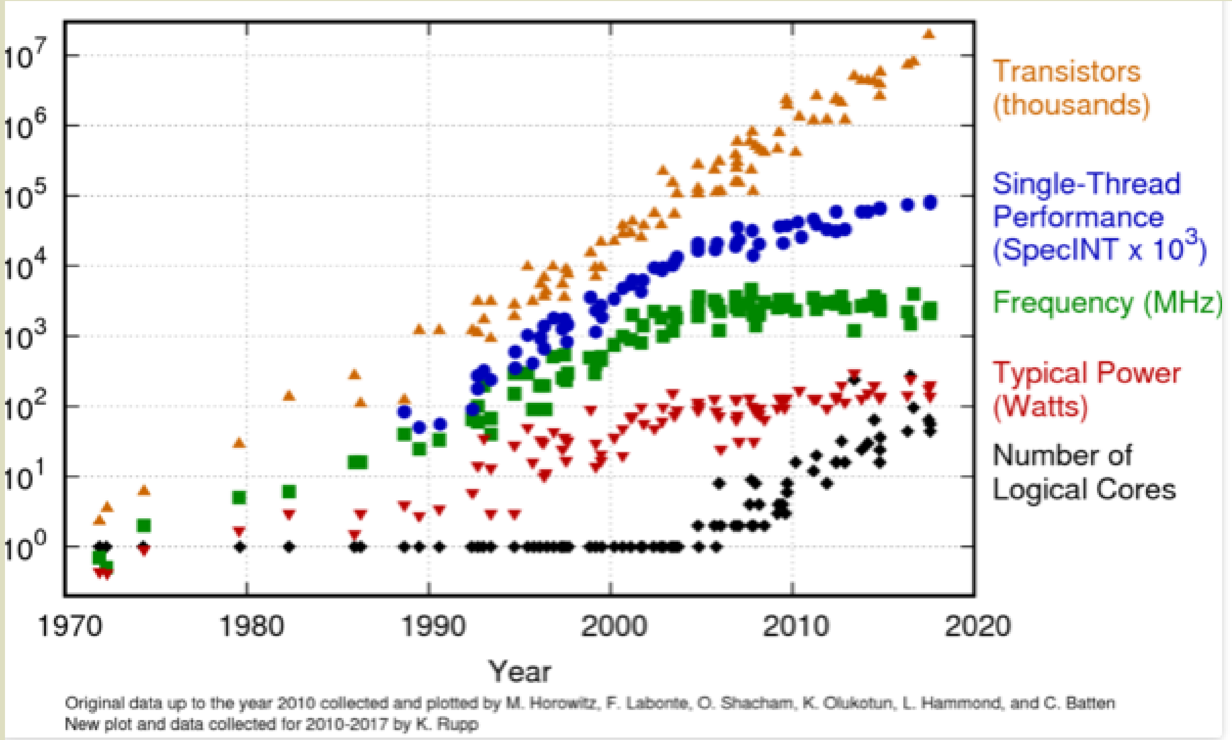
Outline of presentation

- Background
- Theory of heat transfer and thermal interface materials
- Experimental plan, equipment and surface polishing methods
- Results and discussion
- Conclusions

Background

- One of the main limitations is the heat dissipation
- High thermal resistance over interfaces
- Surface roughness is one of the most important factors for the thermal resistance
- Promising solution: Vertically aligned graphene enhanced thermal interface materials



Background – Smart High Tech

- Based on research by Prof. Johan Liu at Chalmers University research graphene enhanced thermal interface materials are made in Gothenburg, Sweden.
- Typical applications are for IC, optoelectronics, and other electronics cooling.
- Throughout this presentation, Smart High Tech product GT50 was used, having a bulk thermal conductivity of 50 W/mK with orthotropic characteristics as shown in fig 1.

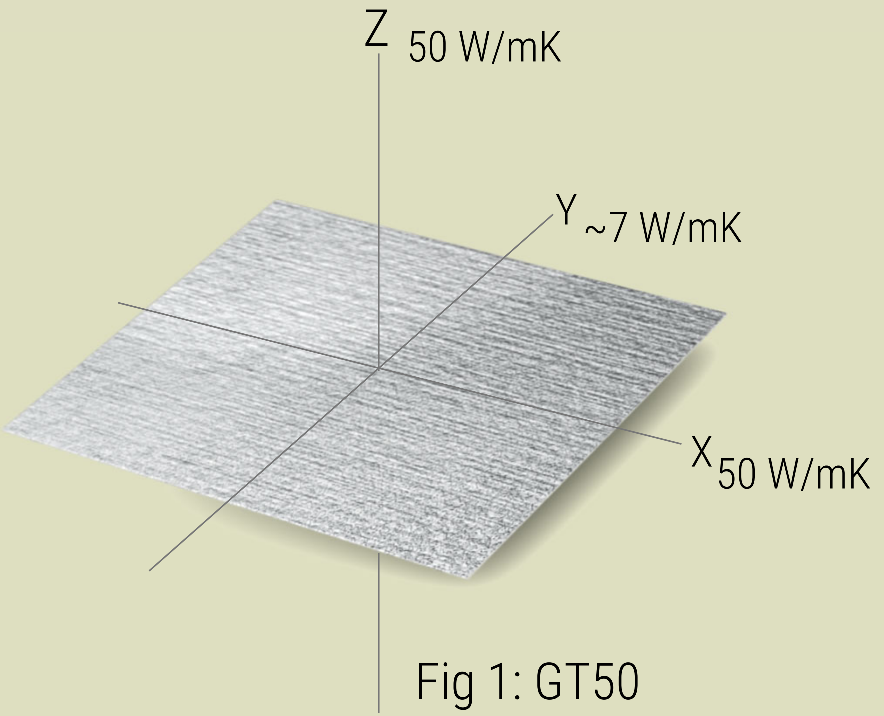


Fig 1: GT50

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Heat transfer between solids: Theory

- Thermal conduction $\propto k\nabla T$

$k_{Al} \approx 240$ W/mK

$k_{Cu} \approx 400$ W/mK

$k_{Si} \approx 150$ W/mK

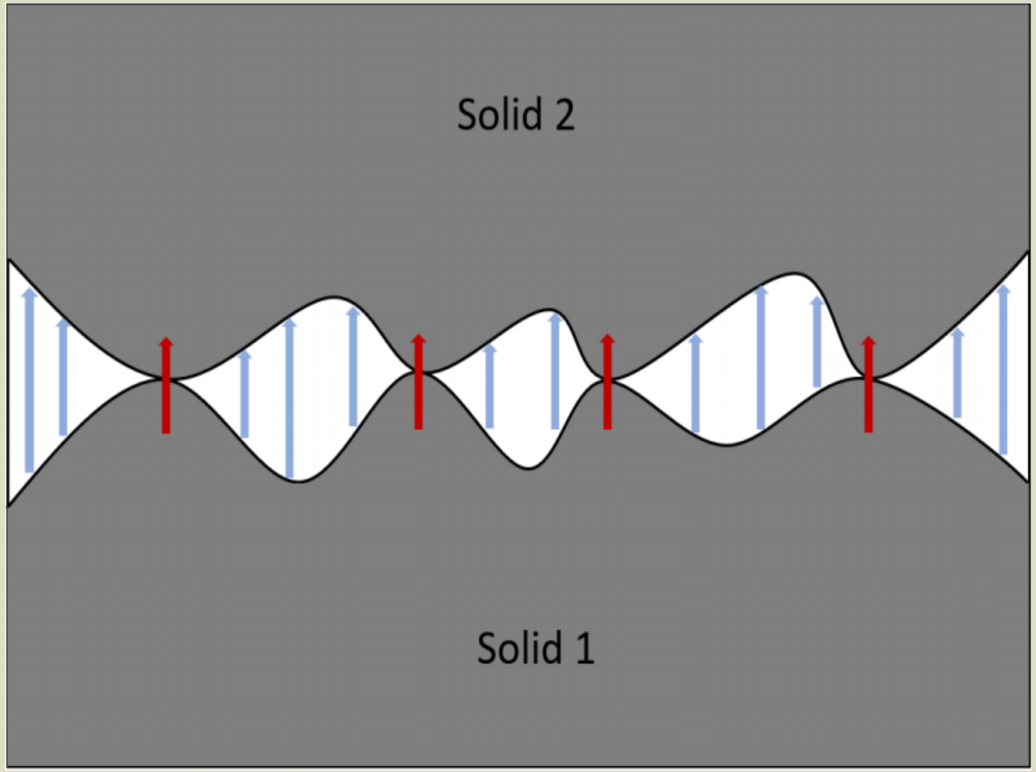
$k_{air} < 0.1$ W/mK

Conduction through air pockets neglected

- Thermal radiation $\propto T^4$

Low at application temperatures

- No convection in steady state



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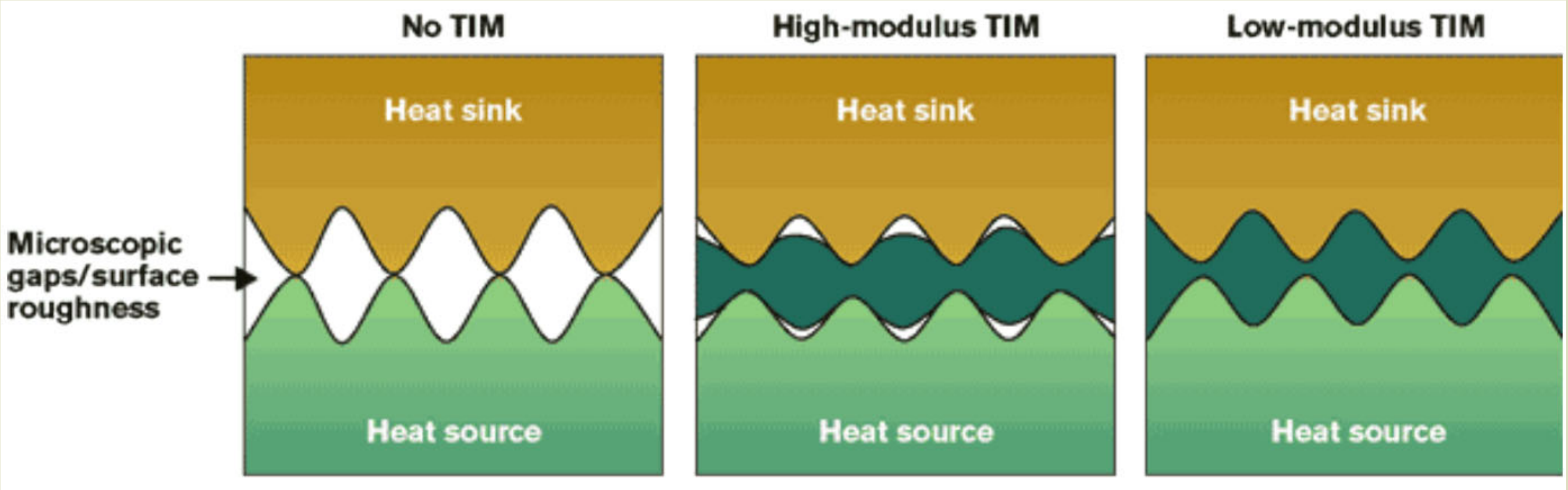
Thermal interface material (TIM)

- Main purpose is to increase contact area

$$R_{TIM} = \frac{BLT}{k_{TIM}}$$

BLT=Average thickness of TIM

$$R_{th} = R_{C1} + R_{TIM} + R_{C2}$$



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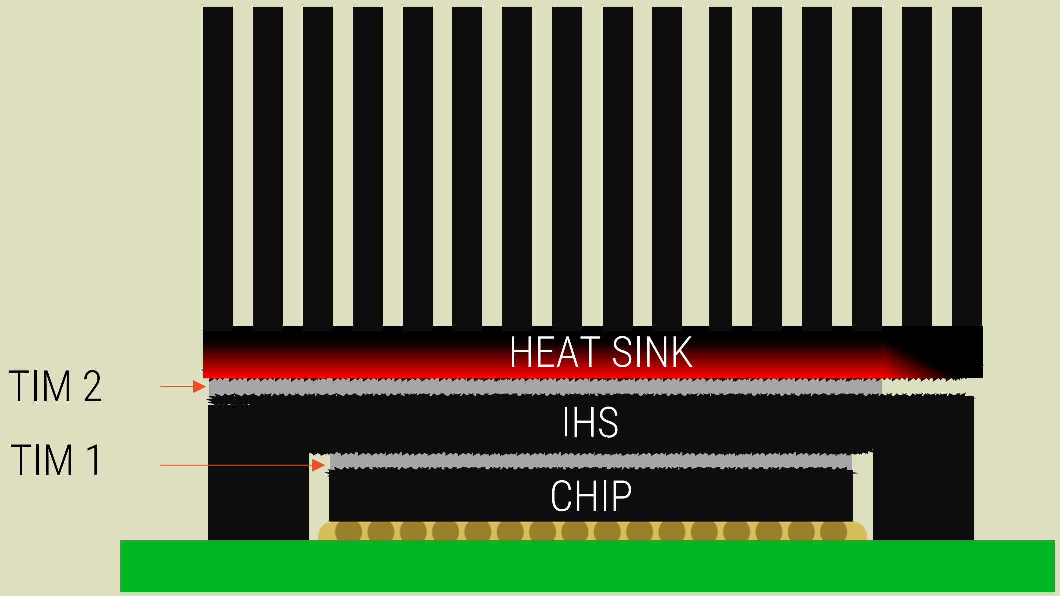
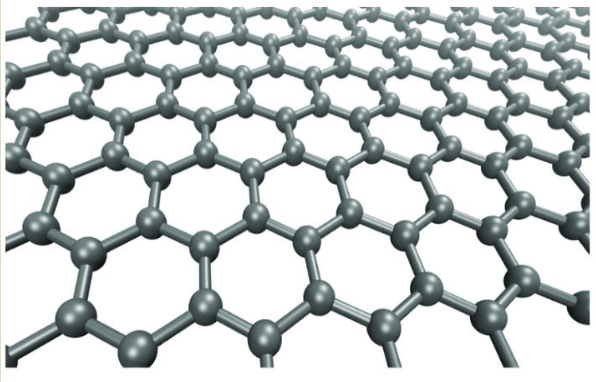
Types of TIMs

- Thermal grease
- Thermal pads
- Phase change materials
- Gels
- Thermal Conductive adhesives
- Solders
- Liquid metals

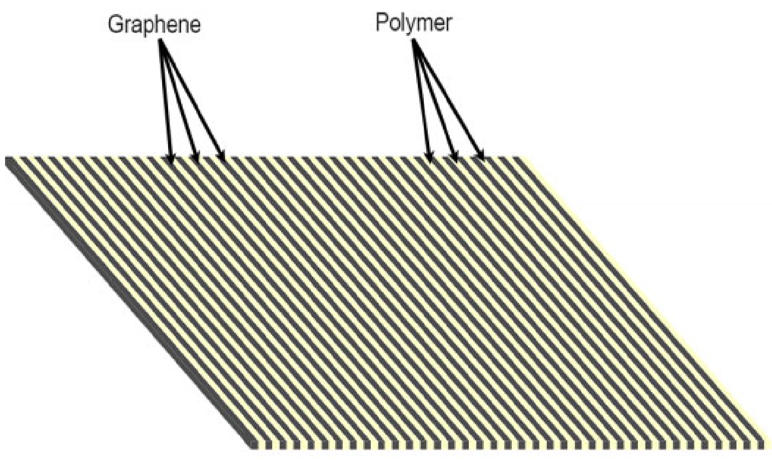
Thermal package



Vertically aligned graphene enhanced TIMs (GT-TIM™)

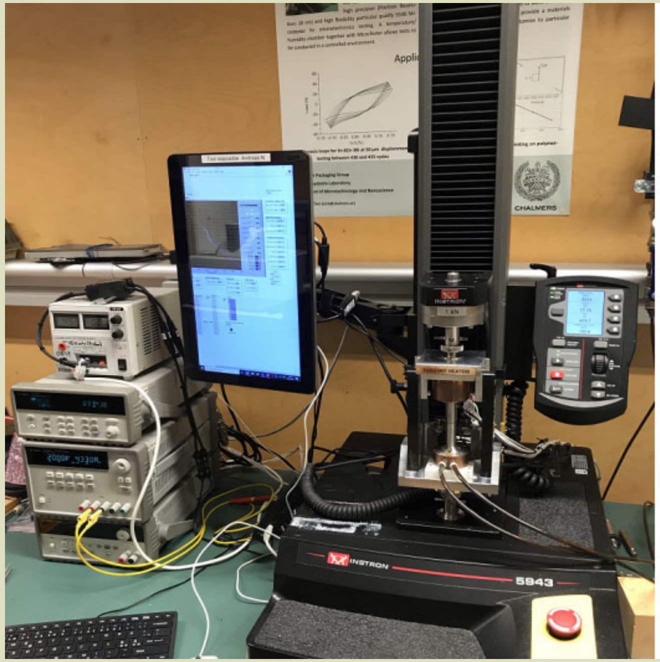


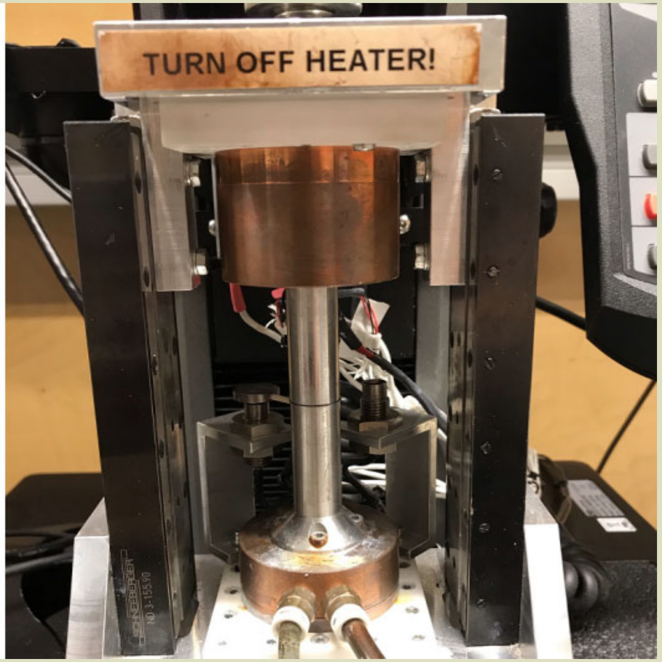
GT-TIM™

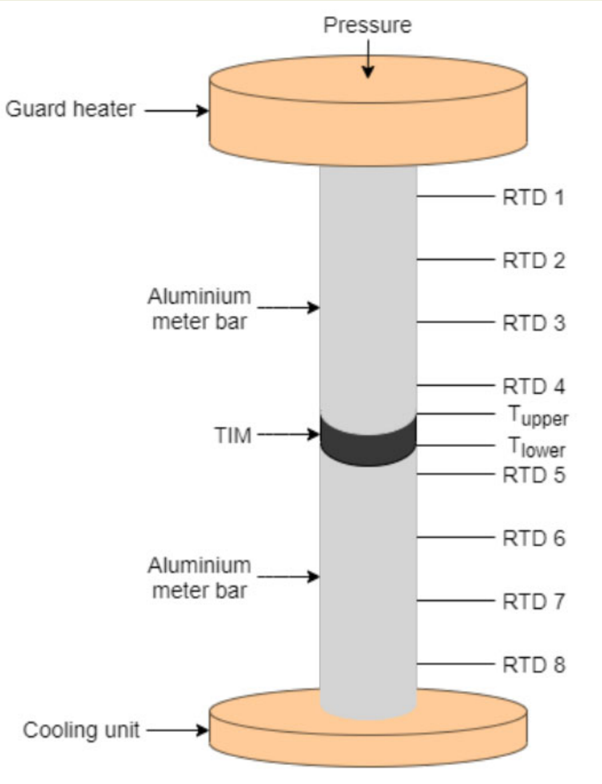


Measuring the thermal interface resistance

- ASTM D5470

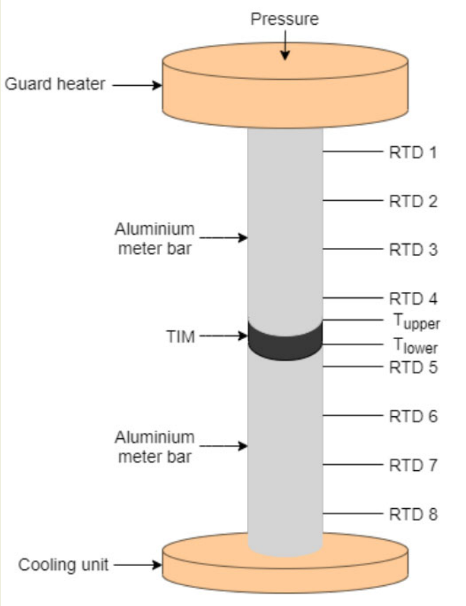


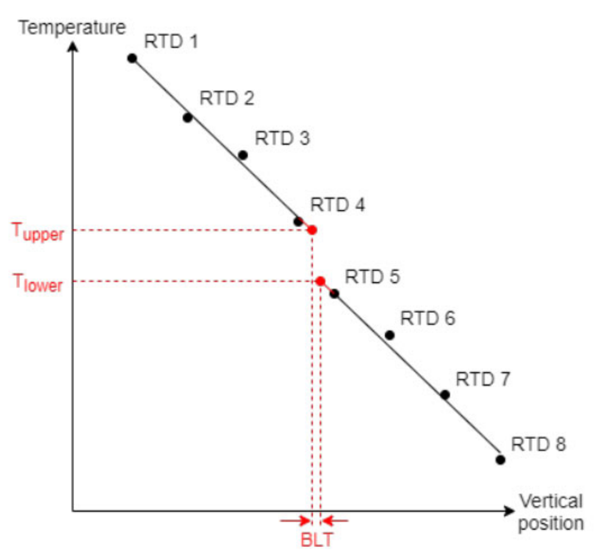


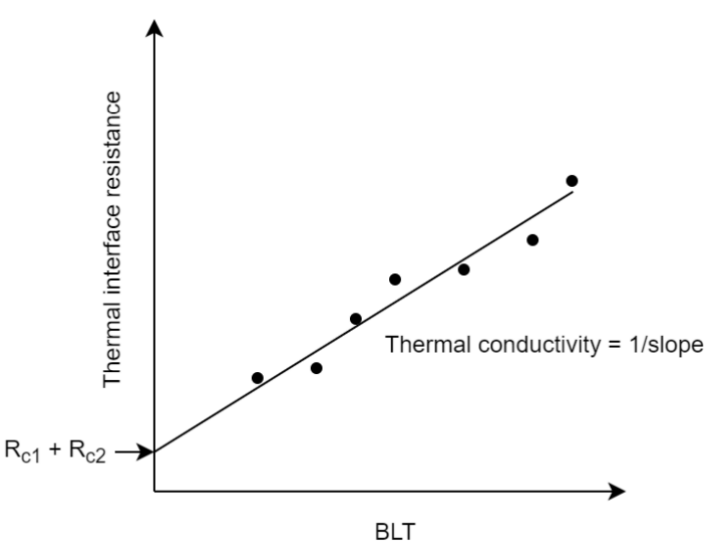


Measure the thermal interface resistance

$$R_{th} = \frac{A}{q}(T_{upper} - T_{lower}),$$

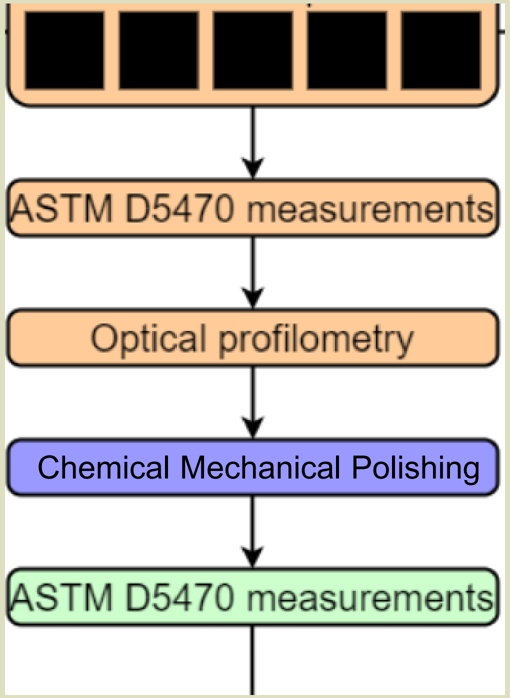






Experimental plan

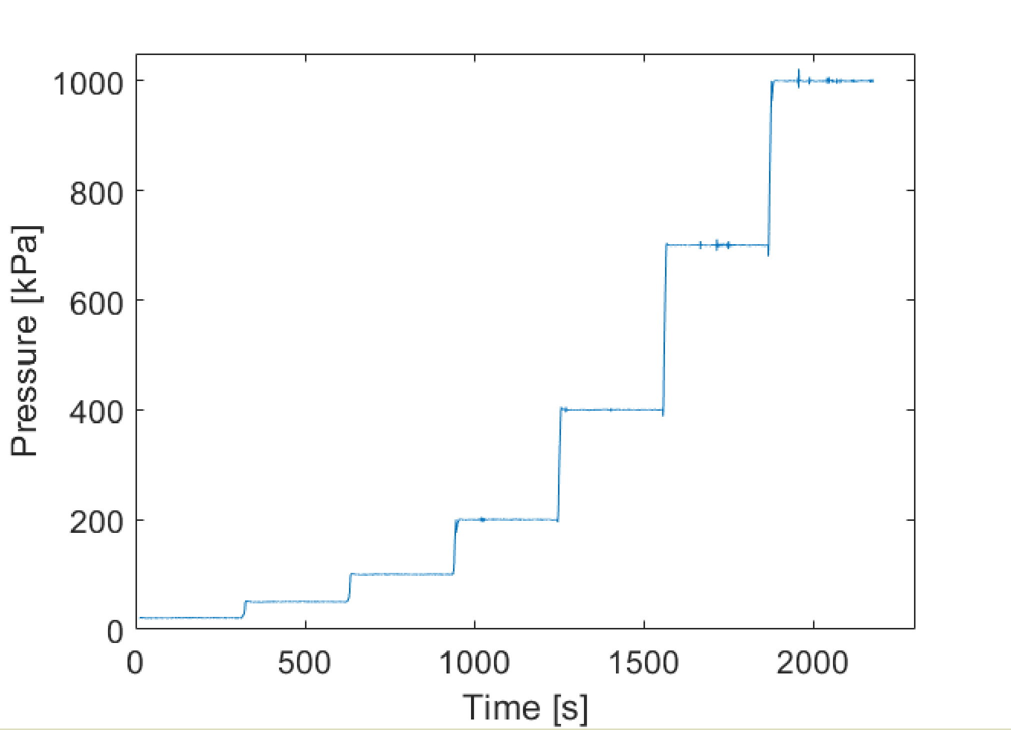
GT-TIM



Surface measurement

ASTM D5470 apparatus measurements

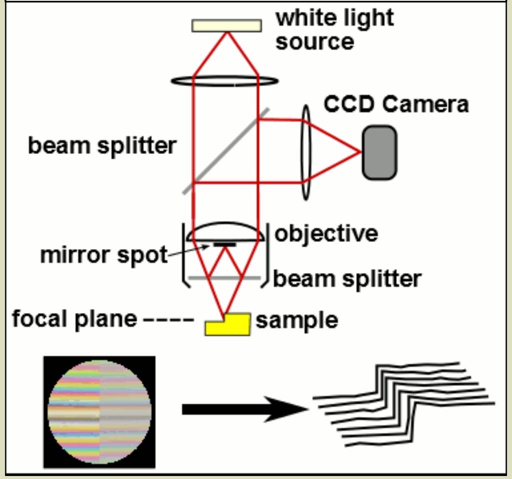
- Pressures: 20, 50, 100, 200, 400, 700, 1000 kPa
- 5 min under pressure
- Power: 30W



Surface roughness evaluation

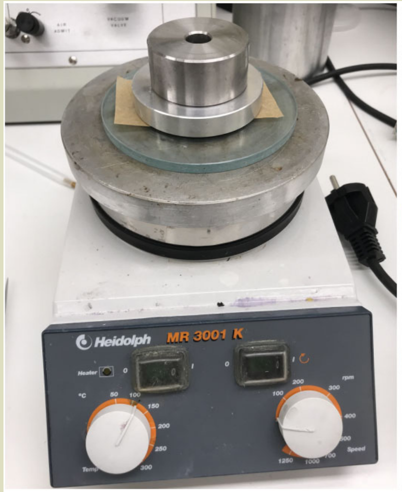
- Surface profiler - Wyko NT 1100
- Vertical scanning interferometry (VSI)
- 20 nm gold coated before

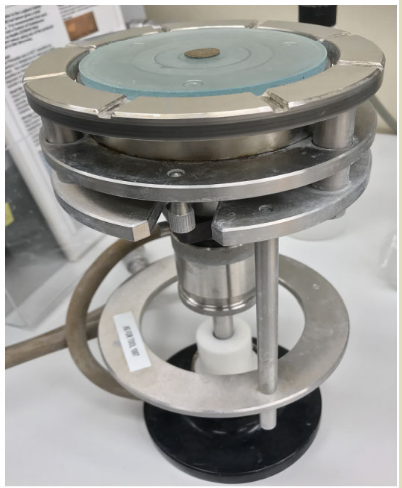
$$S_a = \frac{1}{A} \iint_A |z(x, y)| dx dy,$$



Chemical Mechanical Polishing (CMP)

- 10 min polishing
- Very low pressure
- 50 RPM
- 1-2 drops/s





Tested product parameters

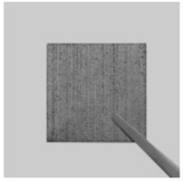
- The product tested was the GT50

SMART HIGH TECH

GT50

Soft and Elastic Graphene Enhanced Thermal Interface Material

Trademark: GT-TIM



Features:

- High Thermal Conductivity
- Low Effective Thermal Resistance
- High Compressibilty and Ultra Light

Applications:

Thermal Burn-In, IC Thermal testing, 5G devices, GPU, CPU, RF, Opto module, IGBT, LED and Power module cooling

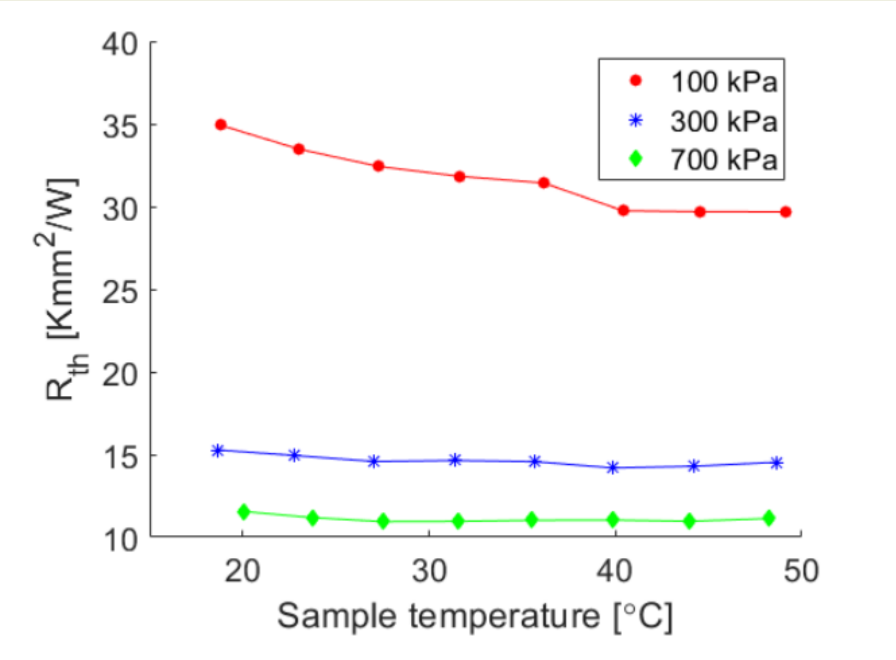
Description:

GT50 is a graphene enhanced thermal Interface material. It has very low effective thermal resistance (12 kmm^2/ W at 275KPa). Moreover, the GT50 has advantages of low density, low complexity during assembly and good maintainability. GT50 opens new opportunities for addressing large heat dissipation issues in electronics and other high power driven systems.

Physical Properties	Value	Units	Test Method
Bulk Thermal Conductivity	50 ± 5 (275KPa, 300μm)	W / mK	ASTM5470
Effective Thermal Resistance	12 ± 1 (275KPa, 300μm)	Kmm^2 / W	ASTM5470
Thickness Range for Production	0.2 - 2	mm	Micrometer
Thickness Tolerance	< 10	%	Micrometer
Pad Size	Up to 55 * 55	mm	-
Compressibility	> 30	%	-
Compressive Strength	1100 ± 50 (300μm)	kPa	At 50% compression
Recovery	> 50	%	-
Tensile Strength	50 ± 20	kPa	Tensile tester
Surface Roughness (Ra)	5 ± 3	μm	Wyko NT1100 optical profilometer
Surface Roughness (Rz)	30 ± 15	μm	Wyko NT1100 optical profilometer
Flammability	V - 0		UL94
Color	Grey	-	Visual

Temperature dependence

- 5, 10, 15, 20, 25, 30, 35 and 40W
- 30 W used for the rest of the measurements ≈ 40 ° C

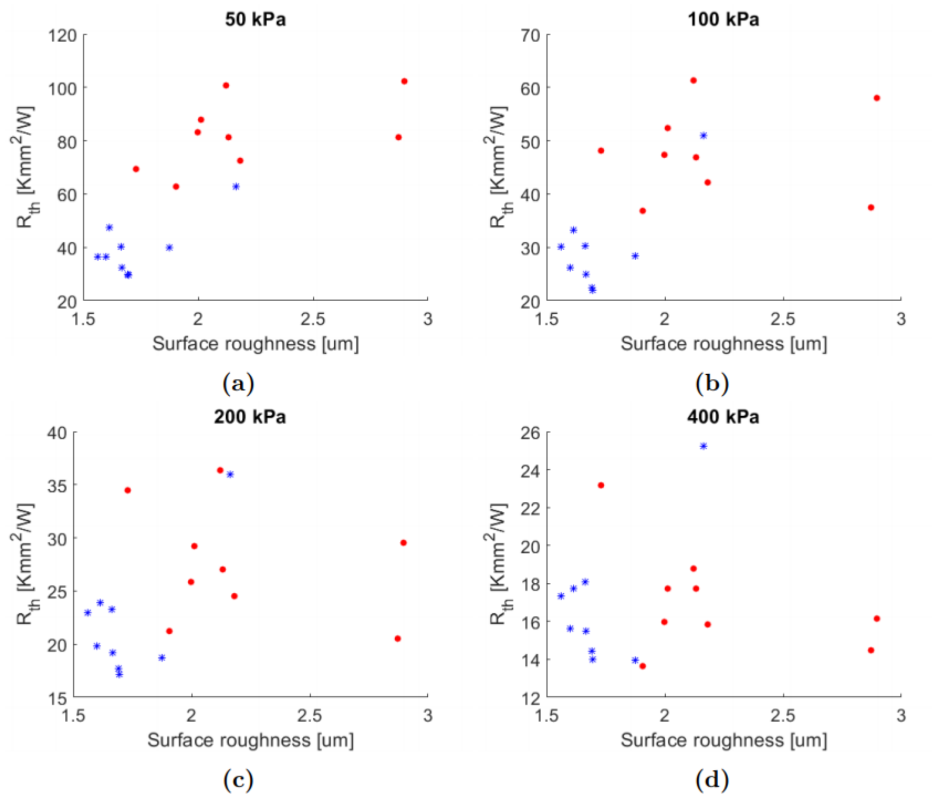


Thermal interface resistance vs Surface roughness

- Below 100 kPa, there are clear indications that surface roughness decreases performance
- Above 400 kPa, no indications that surface roughness has any effect

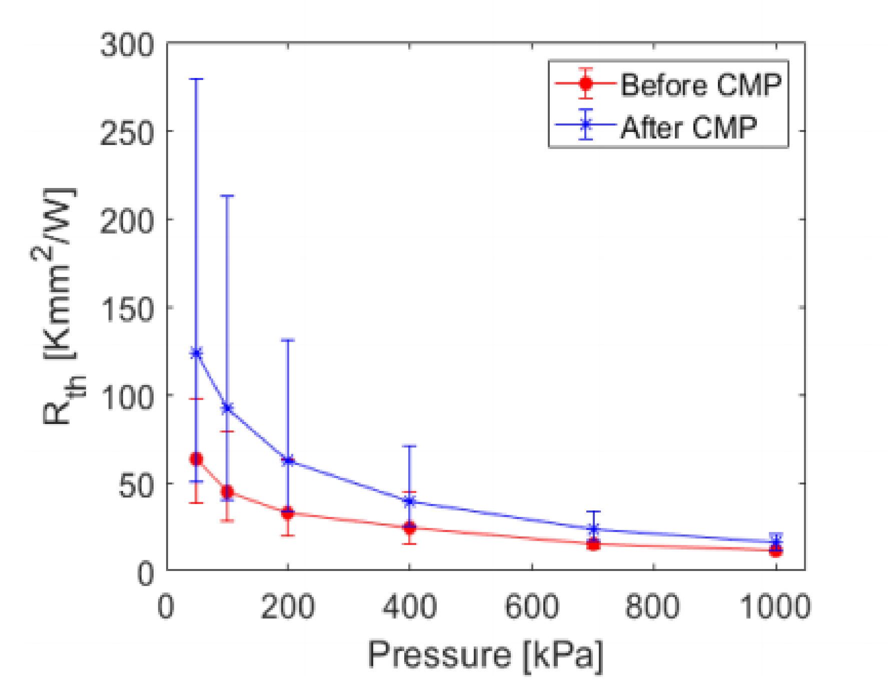
Remarks:

- Different batches (Blue/Red)
- Surface roughness measured after ASTM D5470 (1000 kPa) compression
- Large variation ±18% in original thickness
- Small area measured (10 mm in diameter)



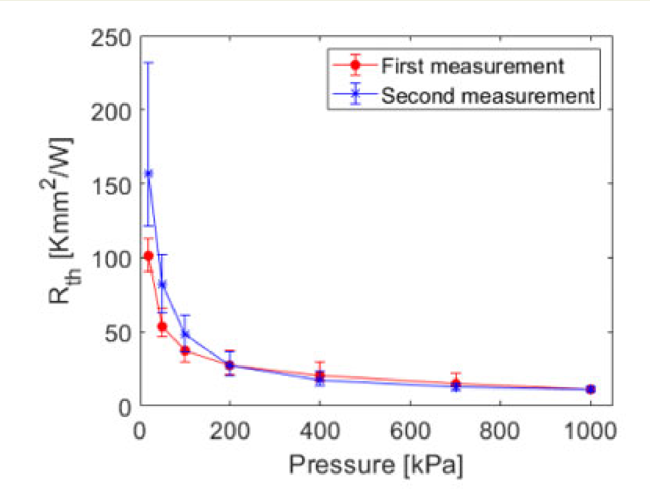
Impact from Chemical Mechanical Polishing

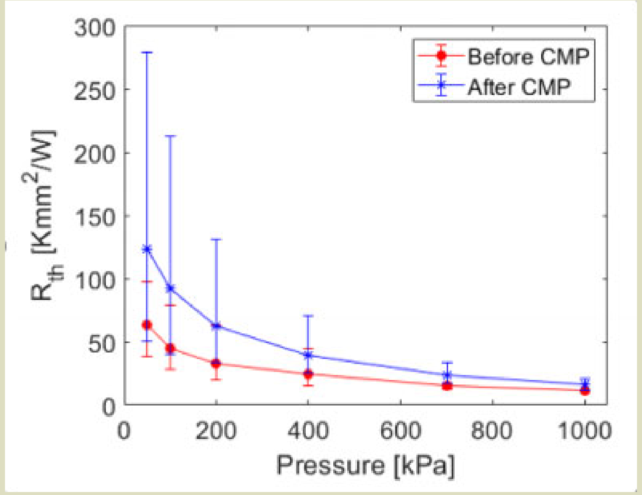
- Thermal interface resistance increases after CMP

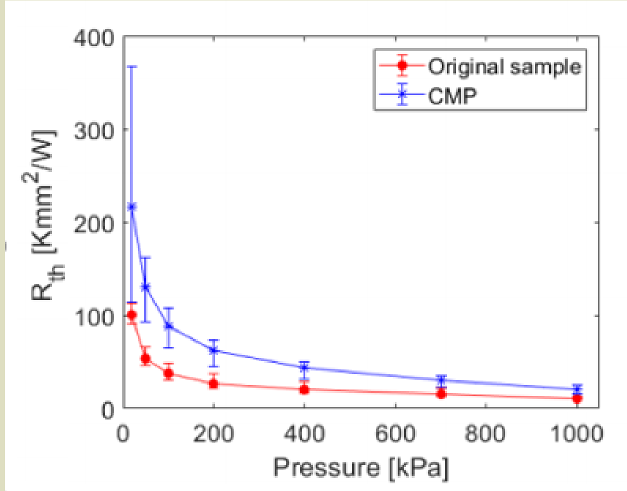


CMP

- ASTM D5470 destructive
- No significant difference







Conclusions

- Destructive bonding method when using CMP
- Large uncertainty of surface roughness and BLT measurements
- GT-TIM (GT50) is not surface roughness dependent for pressures above 400 kPa
- GT-TIM is strongly surface roughness dependent for pressures below 100 KPa
- CMP method used in this work decreases the performance