Dexerials

IMAPS 2021

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Investigation of Carbon Fiber TIM Gap Pad for Enabling Next Generation Automotive High-Power Systems

Dexerials America Corporation

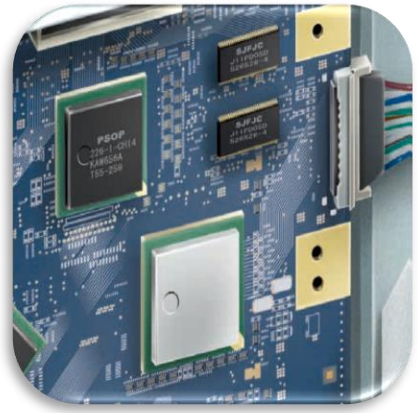
Agenda

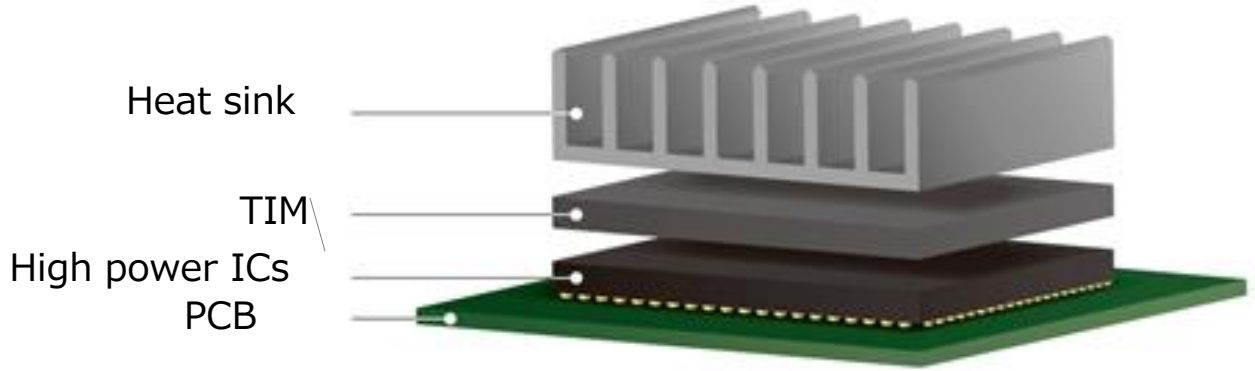
- Introduction
  - TIM Applications
- Thermal Interface Material Design & Comparison
  - Conventional
  - Carbon Fiber
- Packaging Benefits
- Automotive Reliability Results
- Case Studies
- Conclusion

INTRODUCTION

Thermal Interface Material (TIM)

- TIM is placed between heat source and heat sink.
- 3 main functions:
  - Dissipate heat
  - Improve contact of substrates
  - Absorb mechanical tolerance
- TIM needs to balance softness and thermal conductivity.





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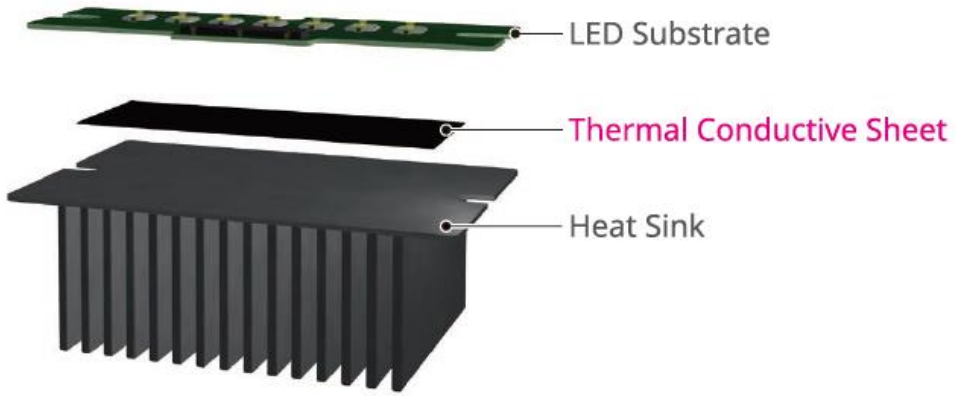
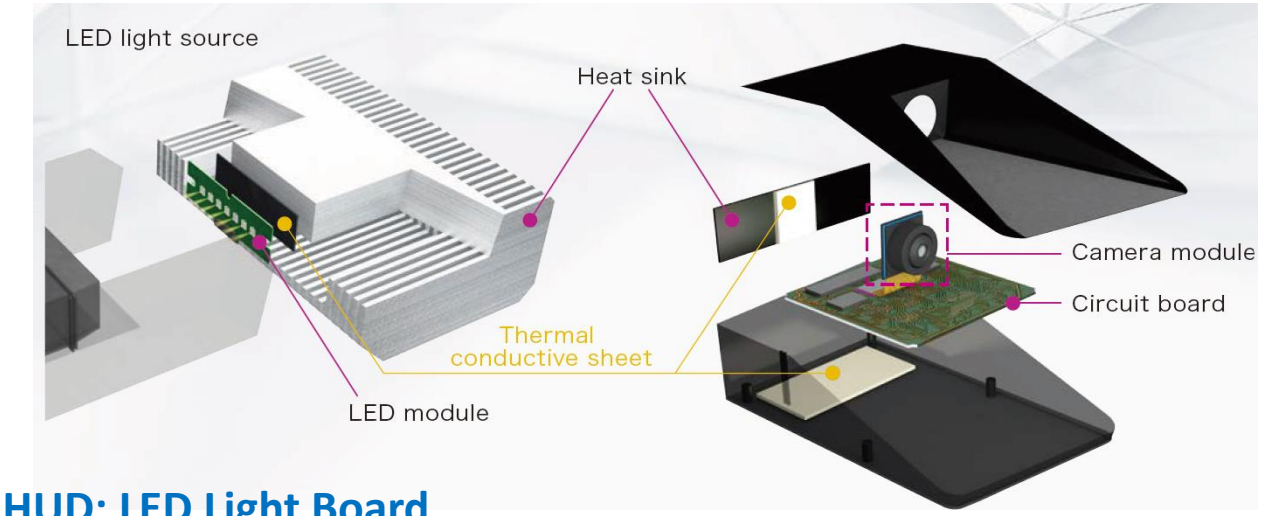
TIM Applications



Lighting: LED Strip



HUD: LED Light Board

ADAS: Camera, Image Sensor

Integrated Circuits: ECU, PCU, GPU, CPU

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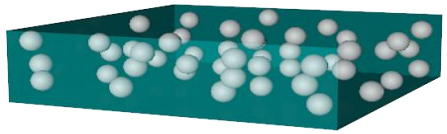
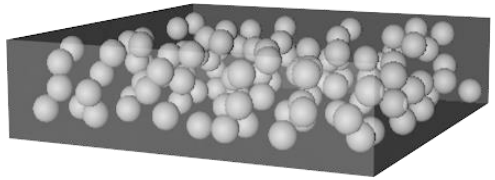
TIM DESIGN & COMPARISON

Dexerials Thermal Conductive Sheet – Gap Pad TIM

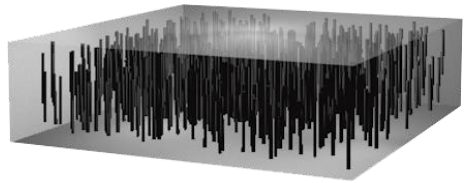
Thermal Conductive Tape

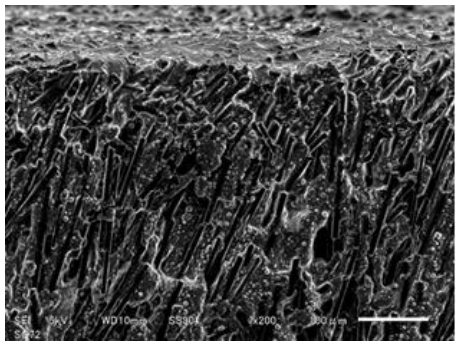


Thermal Interface Material



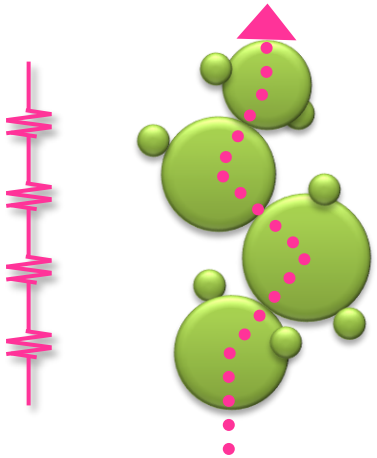
Carbon Fiber Sheet





SEM Image of CFS

Thermal Conductive Filler

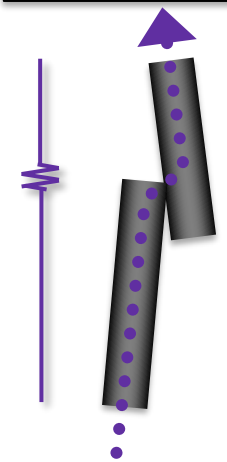


Thermal conductivity of metal particles

AlN **150** W/m·K

and Al2O3 **32** W/m·K

Carbon Fiber Filler



Thermal conductivity of Carbon Fiber

900 W/m·K

Conventional TIM:

- Contains spherical metal fillers.
- Higher metal particle loading equates to higher hardness and thermal conductivity.

Carbon Fiber Sheet (CFS):

- Unique carbon fiber fillers.
- Less contact points between fillers.
- Higher innate thermal conductivity.

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Carbon Fiber Sheet TIM

Part No.	EX10000F7	EX20000C7	EX20000C4S	EX20000C9	Remark
Feature	High Thermal Conductivity	High Thermal Conductivity	High Thermal Conductivity	High Thermal Conductivity	—
Thermal Conductivity	**30**	**35**	**40**	**40**	Unit: W/m・K Estimated Bulk Thermal Conductivity
Color	Gray	Black	Gray	Gray	—
Hardness	50~60	55~65	70~80	50~60	ASTM D2240 Shore OO
Thickness	0.4~3.0	0.5~3.0	0.3～0.5	0.5~3.0	Unit: mm
Compressibility	25	15	2 *@0.3mmT	35	Unit:%/kg・cm2 @1kgf/cm2 250sec 2mmT
Specific Gravity	2.4	2.4	2.4	2.5	—
Dielectric Breakdown Strength	<0.1	<0.1	<0.1	<0.1	AC (kV/mm) ASTM D149
Volume Resistance	1*10^1	1*10^1	1*10^1	1*10^1	Unit: Ω・cm <10^6 JIS K7194 10^6≦ MCC-A method
Dielectric Constant εr' / tanδ@700MHz	21	20	25	19	S parameter method （Coaxial Tube and Waveguide Type） Surface direction value
	0.47	0.3	0.3	0.25	
Flame Rating	V-0	V-0	V-0	V-0	UL94
Preferred Operated Temperature	-40～150	-40～150	-40～150	-40～150	Unit: ℃

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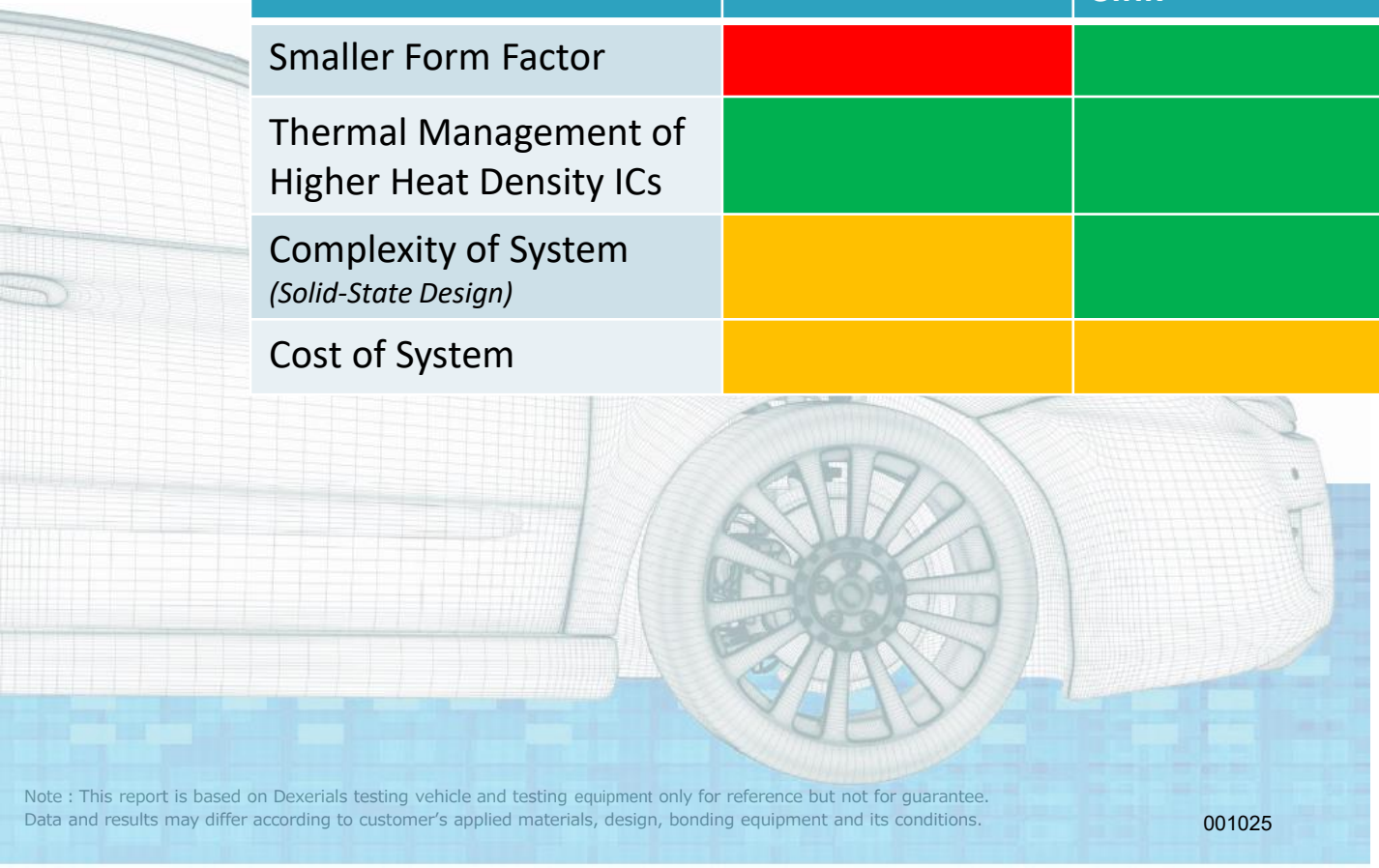
PACKAGING BENEFITS

Thermal Dissipation Strategies Comparison

	Increase Heat Sink Size	Higher Conductivity Heat Sink	Higher Conductivity TIM (CFS TIM)	Increased Airflow Rate / Add Fan
Smaller Form Factor				
Thermal Management of Higher Heat Density ICs				
Complexity of System *(Solid-State Design)*				
Cost of System				



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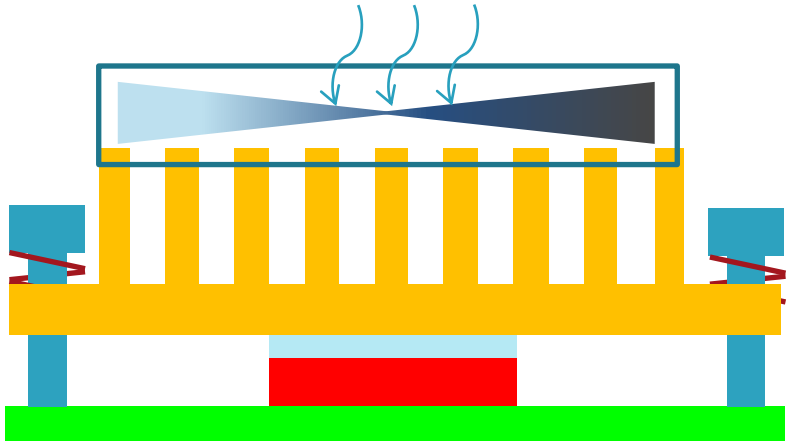
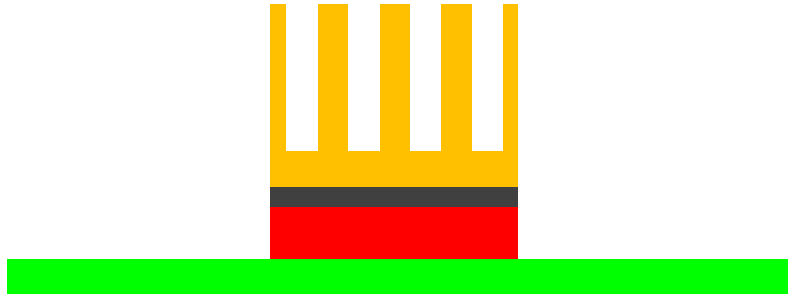
Lower Thermal Resistance (Low R_{th})

$$R_{total} = R_{HS} + R_{TIM}$$



Low R_{HS} + High R_{TIM}
Large heat sink + conventional TIM



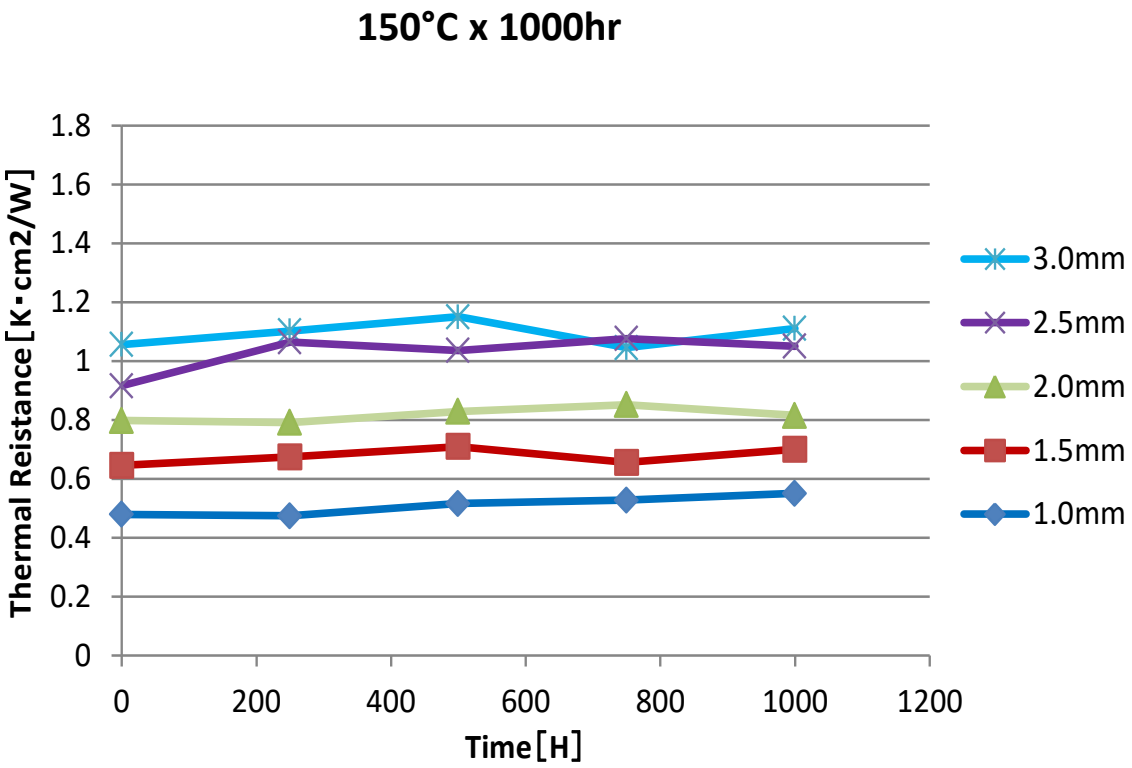
High R_{HS} + Low R_{TIM}
Small heat sink + CFS TIM

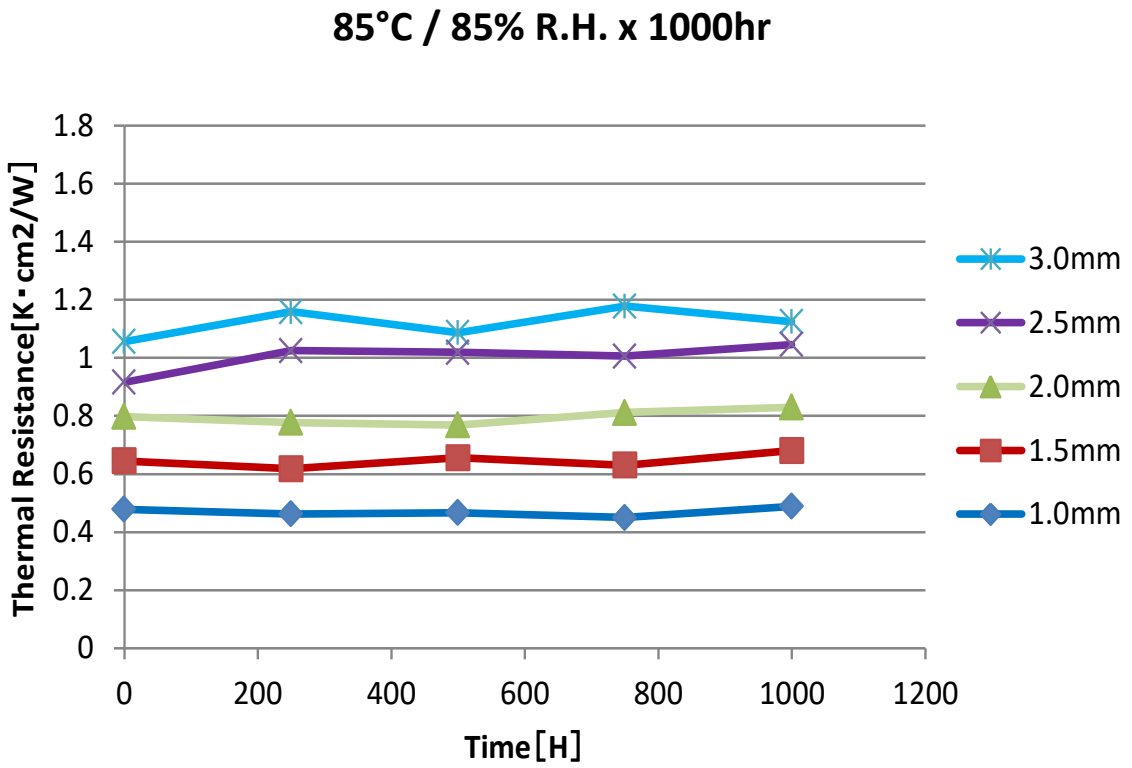
Benefits of Low R_{th} TIM:

- Allows for higher thermal budget of heat sink (smaller heat sink).
- Smaller components help with downsizing system.

AUTOMOTIVE RELIABILITY RESULTS

Automotive Reliability Test Result





Reliability Results:

- CFS TIM in various thicknesses showed little to no change in thermal resistance.

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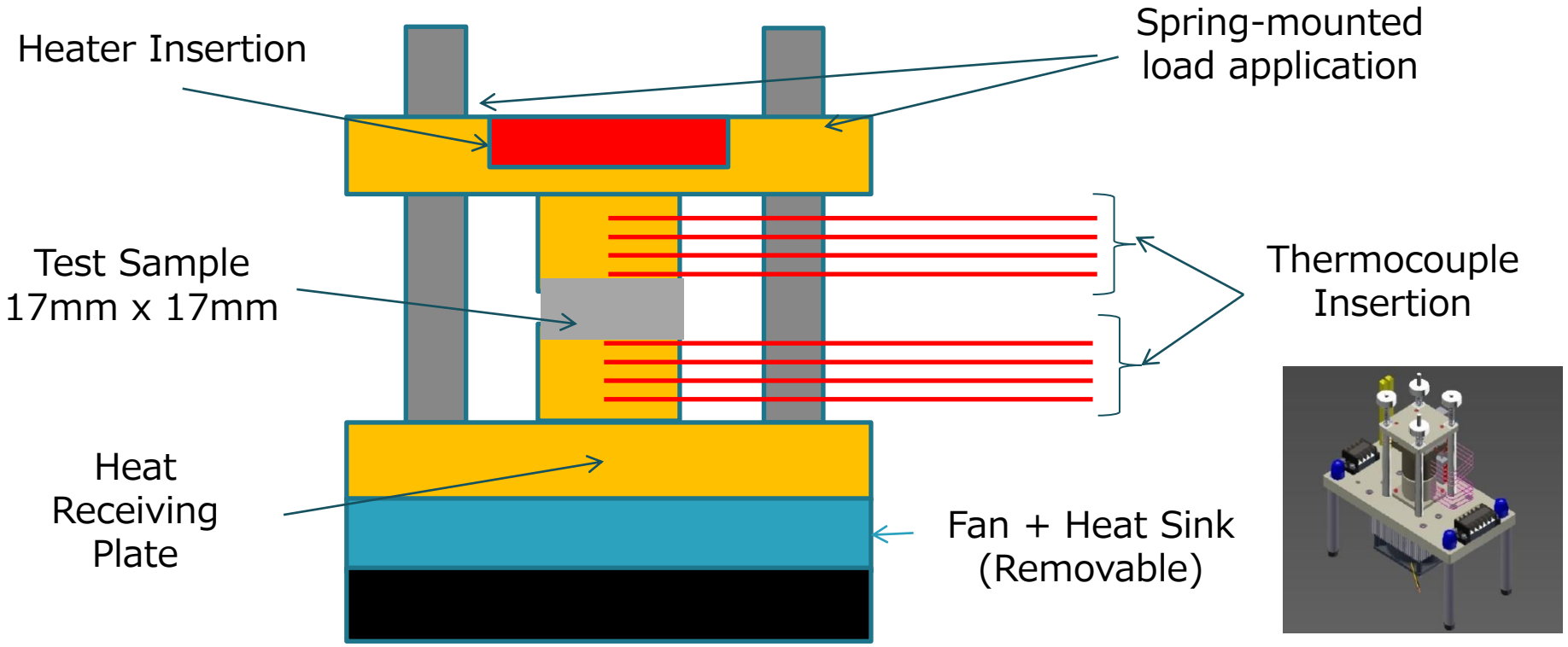
Loaded Reliability Test Equipment



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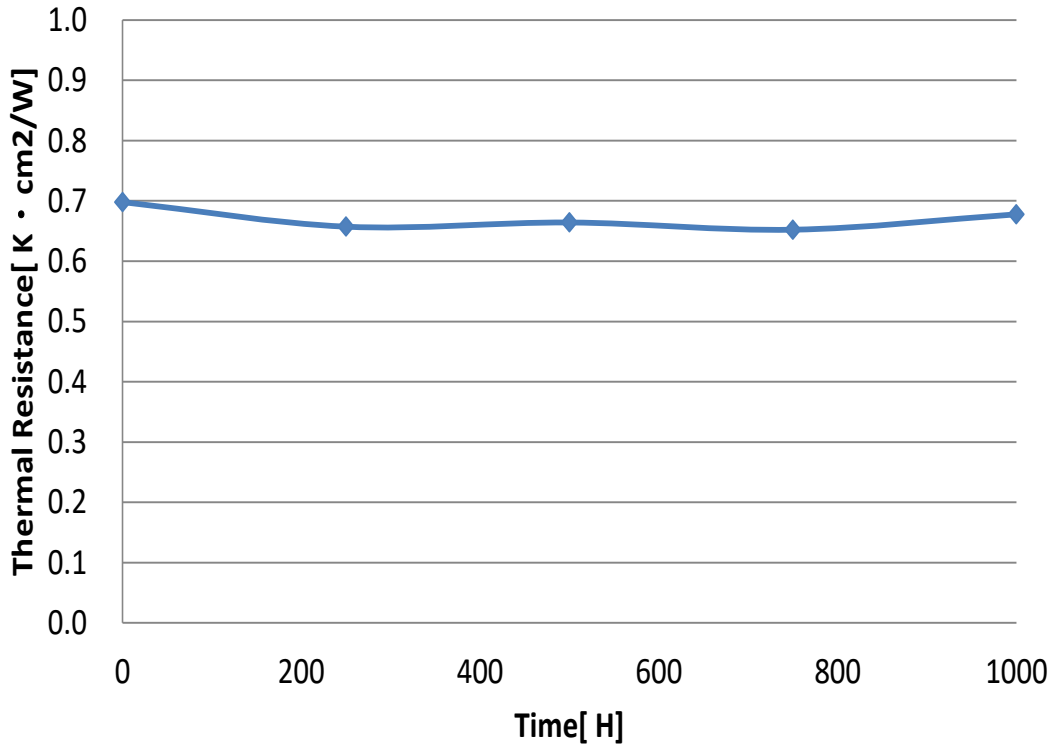
Loaded Reliability Test Result – 150°C



Model : EX20150C7
Thickness : 1.5mm
Load : 7psi
Test temperature : 150℃

Constant Pressure Reliability Results:

- CFS TIM showed very stable thermal resistance after 1000hrs.

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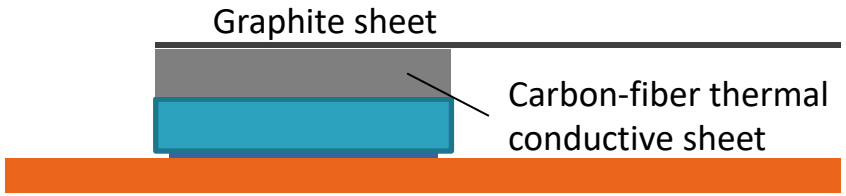
CASE STUDIES

Case Study #1: Power Module Test Setup

1. Reference

2. CFS + graphite sheet



3. CFS + graphite sheet + heat sink

List of an experiment conditions.

Input power	0.84 W
Ambient temp.	25 ℃
Air flow	0 m/s

List of parts used for power module board experiment.

Part name	Thermal Resistance (R_{th}) [K/W]	Size	Remarks
Heat sink UB4060-15B	7	40mm X 60mm X 1mm	R_{th} was measured without fans.
CFS 30W/mK thermal conductivity	0.42	10mm X 10mm X 1mm	R_{th} was measured in vertical direction to the sheet
Graphite sheet	35	56mm X 56mm X 0.02mm	R_{th} was measured when using the sheet as a heat sink, without fans.

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Case Study #1: Power Module Results

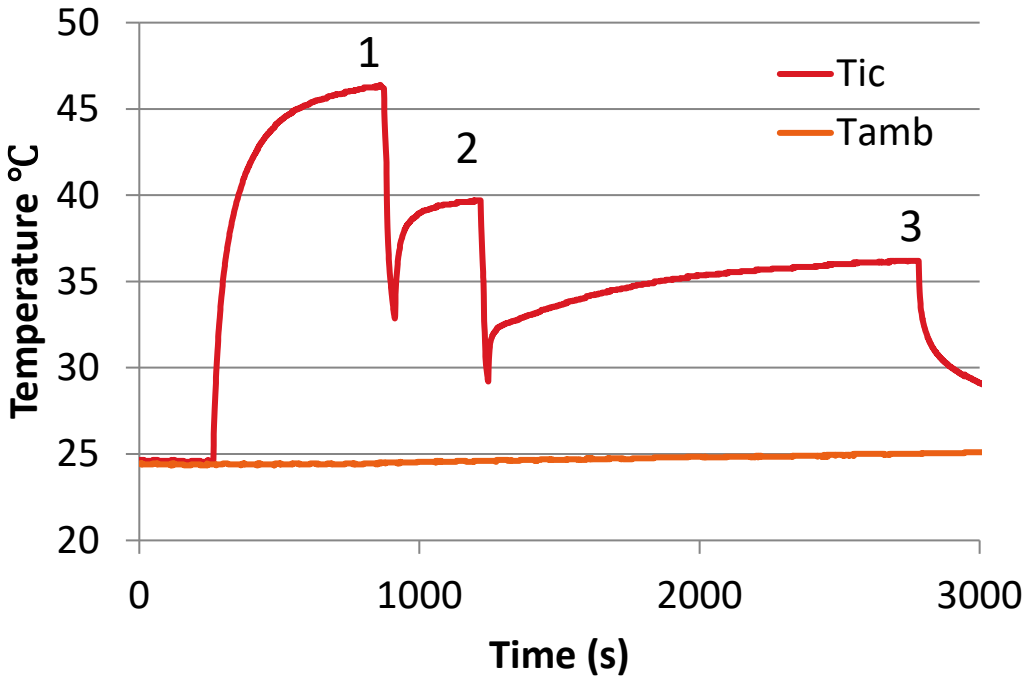


Figure: The IC and ambient temperature during the test.

Table : R_{total} calculations from results of study

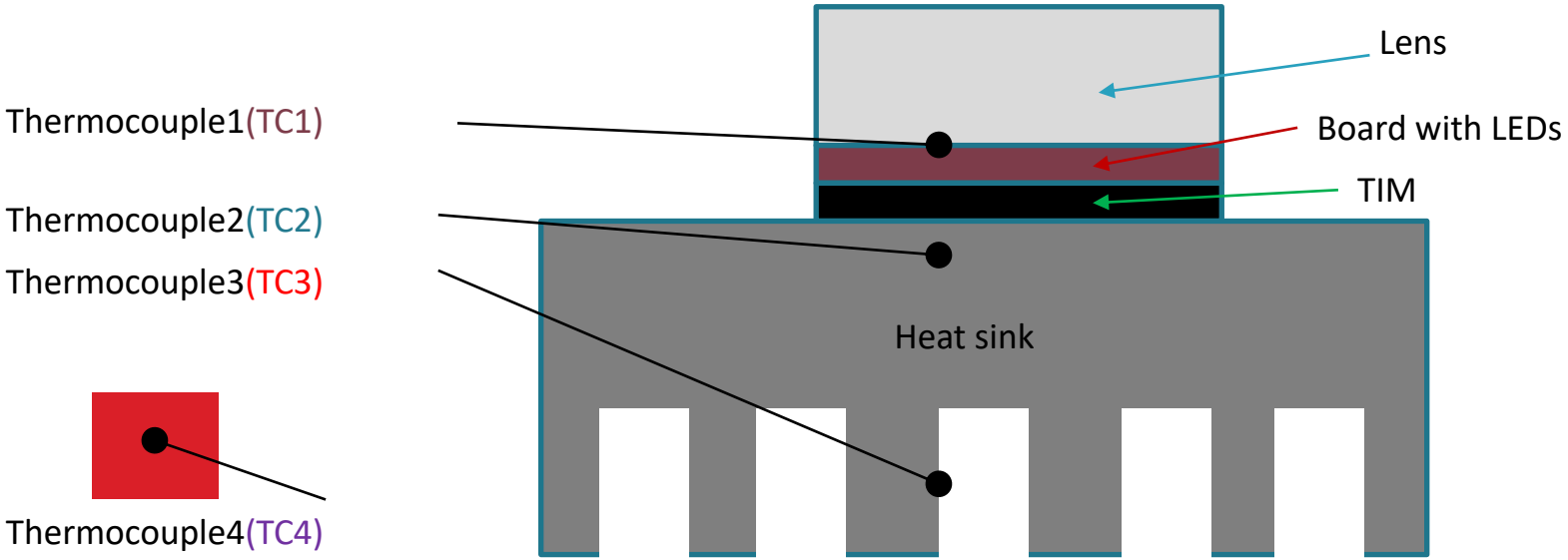
Using P = 0.84W	T_{ic} (℃);Temp of IC	R_{total}(K/W); Thermal resistance of system
1. Reference	46.3	26.0
2. CFS + graphite sheet	39.6	17.9
3. CFS + graphite sheet + heat sink	36.2	13.3

Thermal resistance was lowest in setup #3 CFS + graphite sheet + heat sink.

Case Study #2: LED Board Test Setup

Thermocouples are set on surface.

Applied Voltage 19V / Amps 0.3A.



TIM	Thickness mm
Dexerials 3W/mK	0.5
Dexerials CFS 15W/mK	0.4

Results:

TIM	TC1 ℃	TC2 ℃	TC3 ℃	TC4℃	Power W	R_{IC-HS} K/W
Dexerials 3W/mK	**36.11**	32.7	32.4	25.95	5.61	**0.608**
Dexerials CFS 15W/mK	**29.15**	29.3	29.1	25.4	5.64	**0.274**

Data measured 2 minutes after LED are powered on.

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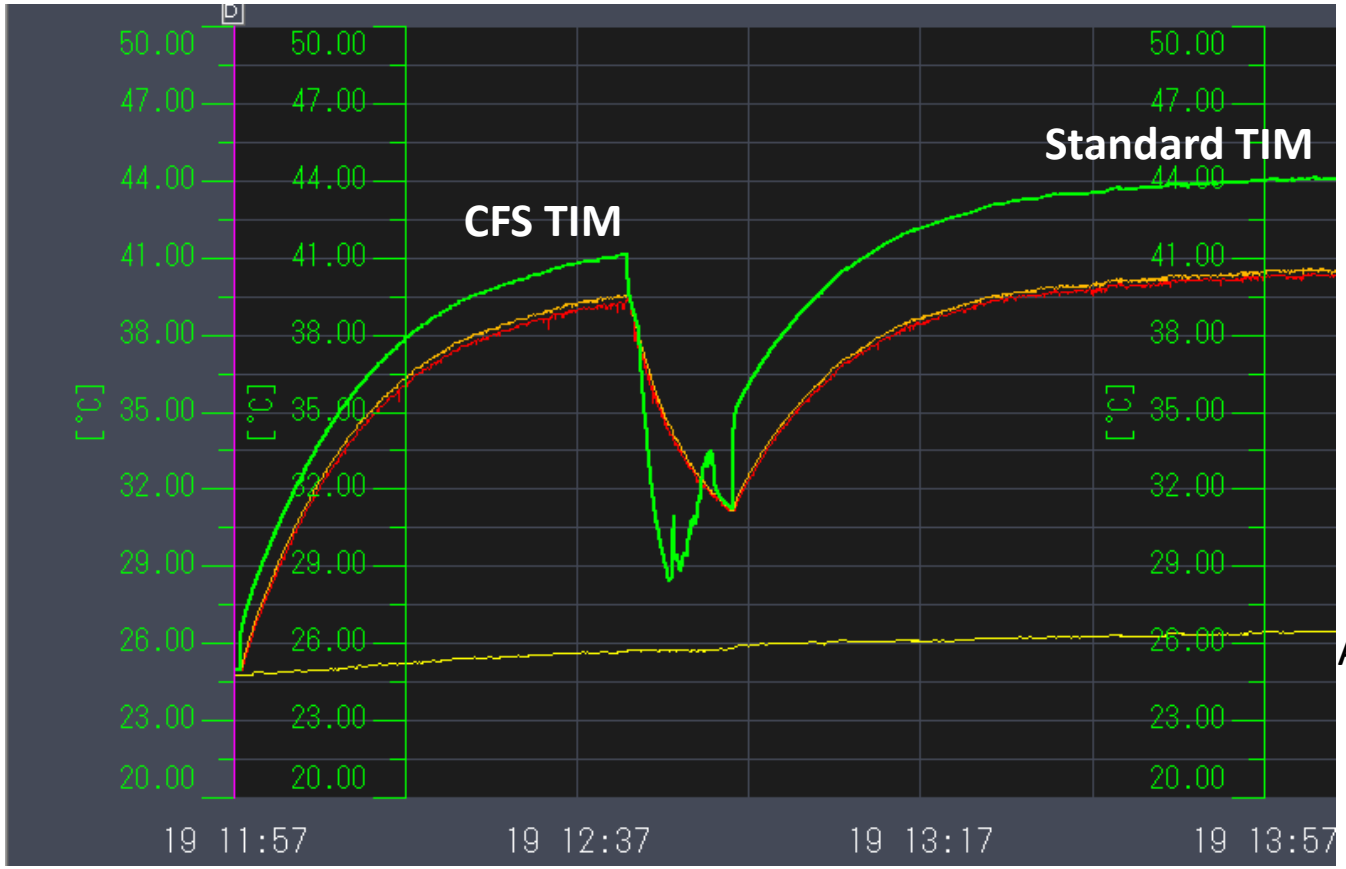
Case Study #2: LED Board Results



On board(TC1)

Heat sink1(TC2)
Heat sink2(TC3)

Ambient(TC4)

Measured Data		3W/mK Conventional	**15W/mK CFS**
Thermal conductivity	W/mK	1.6	15
Width	mm	20	20
Length	mm	50	50
Thickness	mm	0.5	0.4
Thermal Resistance	K/W	0.61	0.27
Thermal contact resistance		**0.30**	**0.24**

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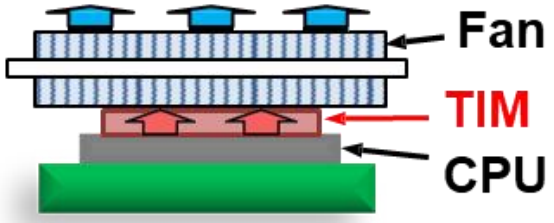
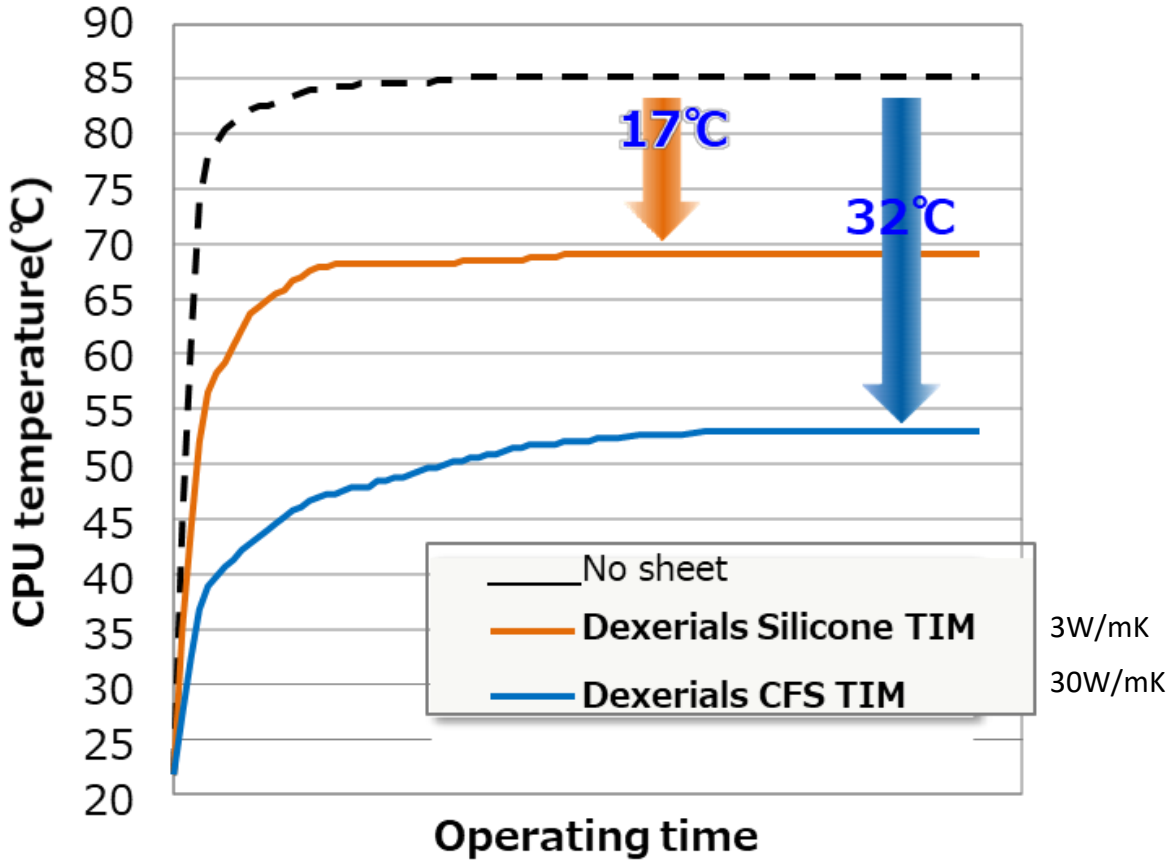
Case #3: 8-Core Processor

Temperature of CPU with TIM sheet





3W/mK

30W/mK

List of an experiment conditions.

Input power	5 W
Ambient temp.	25 ℃

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Conclusion

- **Dexerials' automotive-ready Carbon Fiber Sheet TIM can meet the rising thermal cooling requirements in next generation automobiles.**
- **Employing CFS TIM has proven to reduce IC temperature and stabilize system performance.**
- **Higher conductivity TIM can enable downsizing of package size or lower air cooling requirements in high heat density ICs.**

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Value Matters

Unprecedented innovation, unprecedented value.