Panasonic

THERMAL Solutions

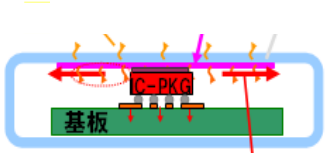
PGS® Graphite Sheet and Thermal Solution Products

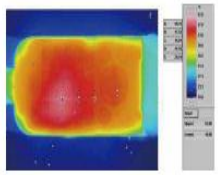
Sep. 2015

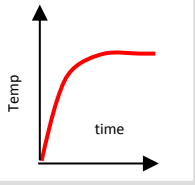
Device Solutions Business Division
Automotive & Industrial Systems Company
Panasonic Corporation

Thermal Solution line-up

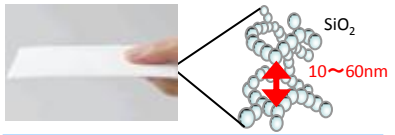
Thermal & EMC simulation







NASBIS
Nano Silica Balloon thermal Insulator



- Higher insulation than air
- Min. thickness 50um
- Flexible

Design support

Aerogel Insulator

New Spreader

Graphite Spreader

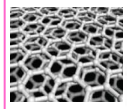
PGS + SSM
(Semi Sealing Material)

- Squeeze out of whole PCB
- 1.6 W/mk t=0.5 - 3mm

PGS + TSS
(Thermal Storage Sheet)

- Prevent rapid temp. rise
- t=0.25 - 0.65mm

PGS
Pyrolytic Graphite Sheet



- 2-5X conductivity of Cu
- t=10 -100um

LD PGS
low Dencity

- Higher transferable heat Z direction

Graphite PAD
(Thermal interface)

- .5X contact resistance
- 10-20W/mK /Z-axis
- t=500 - 3000um

Heat Spreading (X-Y plane)

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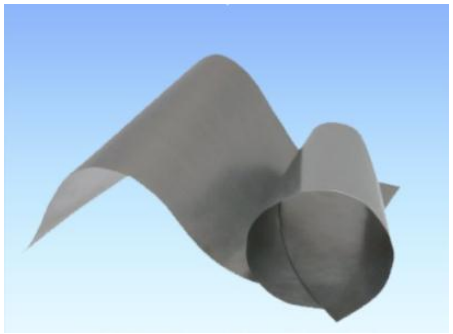
PGS Graphite Sheet



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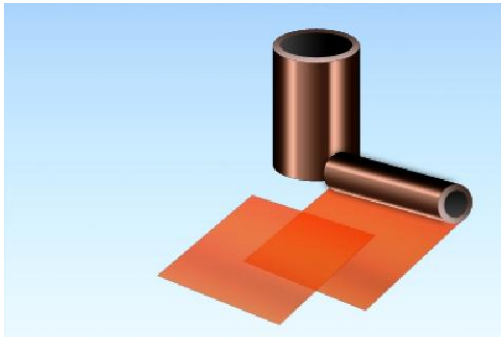
Structure of PGS® Graphite sheet

The polymer graphitizing method

Panasonic original

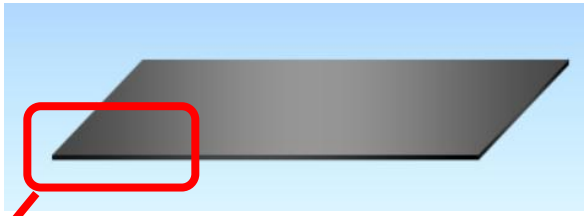


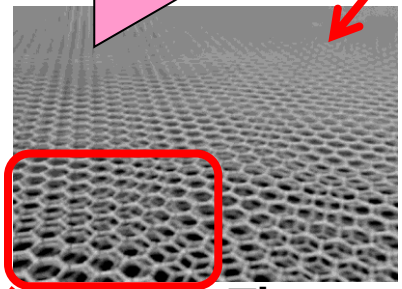
Material: Polymer film

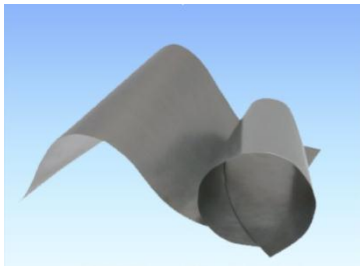
Pyrolysis

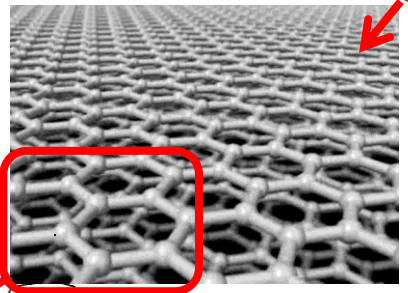
↓

Crystallizing Graphite



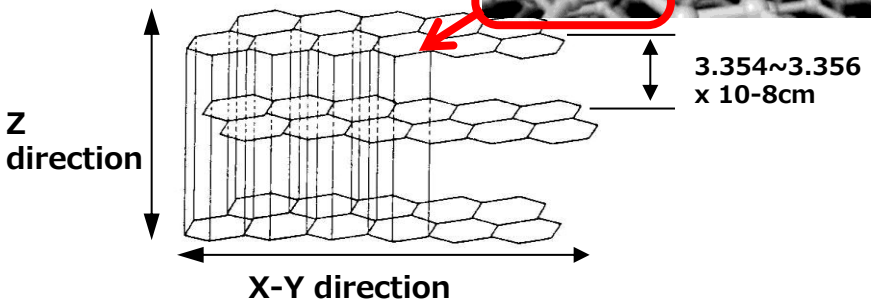






The crystallized graphite is uniformed in horizontal direction.

[Structure]



High-level thermal conductivity

・Best thermal conductivity in the industry.
700～1,900 （W/m K）

Flexibility

PGS is bending-resistant due to its flexibility.
PGS can be used for curved surfaces and corners because heat conductivity of PGS will remain unchanged in the absence of sharp folds.

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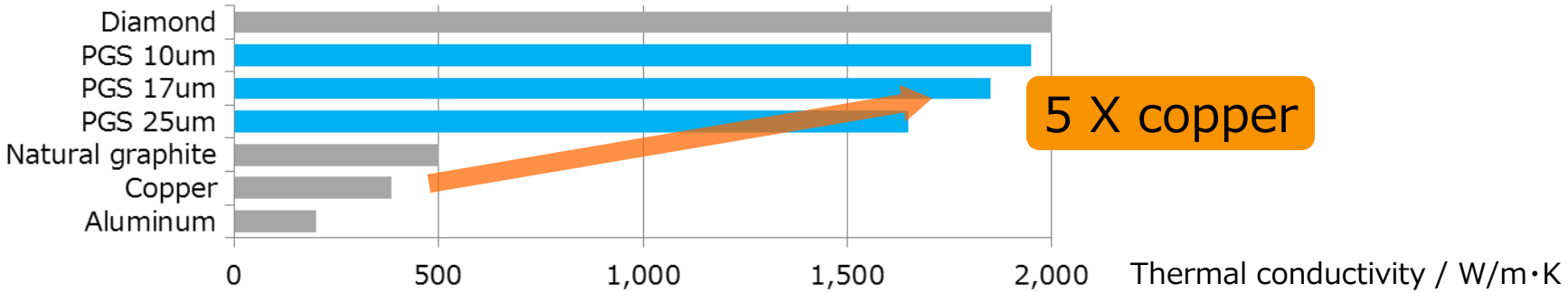
Feature of PGS® Graphite sheet

Ultra High Thermal Conductivity | Light Weight | High intensity

HighThermal @ Thin

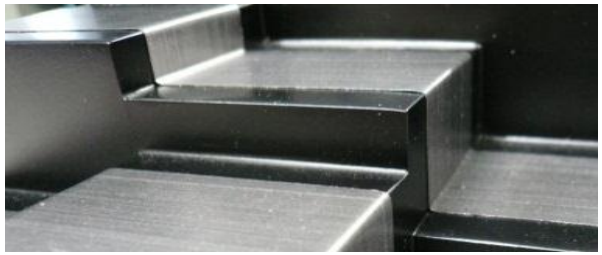
1) Thin with high thermal conductivity,5 times of copper heat control available while remaining thin / lightweight.



Flexible Bendable

2) Easily-work & fixing (tiny or complex shape)

More freedom in design than other sheet material like natural graphite or copper sheet



Bendable (thermal conductivity not affected)

Suitable for curved surface/edge

Shielding Stability

3) Simultaneous solution for thermal and electromagnetic wave problem.

4) Environmentally resistant, no deterioration with age.

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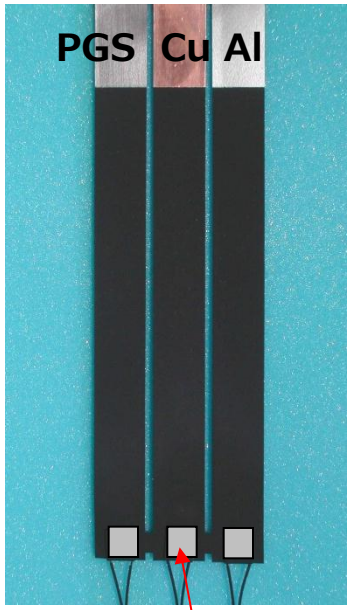
Application example (Transfer)

PGS Graphite Sheet

■ **Inspection 1**

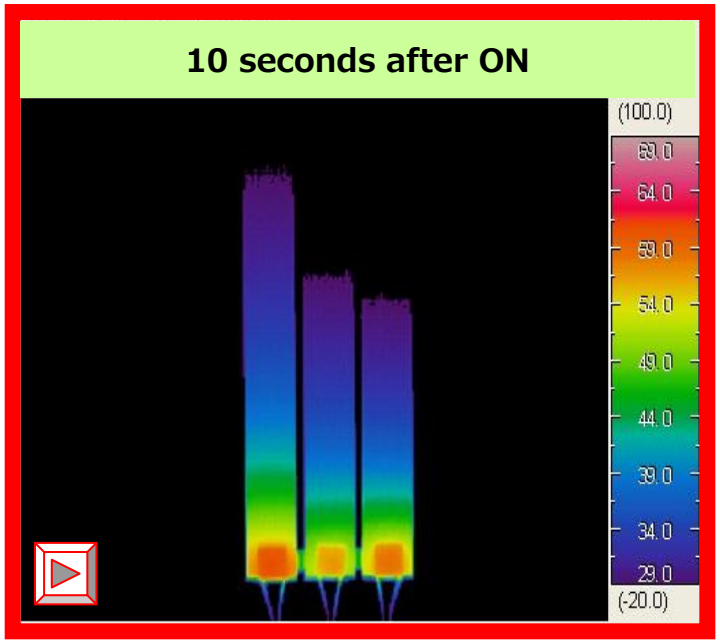
The heat transfer was monitored with thermograph after the heater was attached to the lower part of PGS, Copper and Aluminum.

Test sample
Size;18x180x0.1mm



Resistance heater ;10x10mm
Applied voltage ; 8V
(approx.12W)

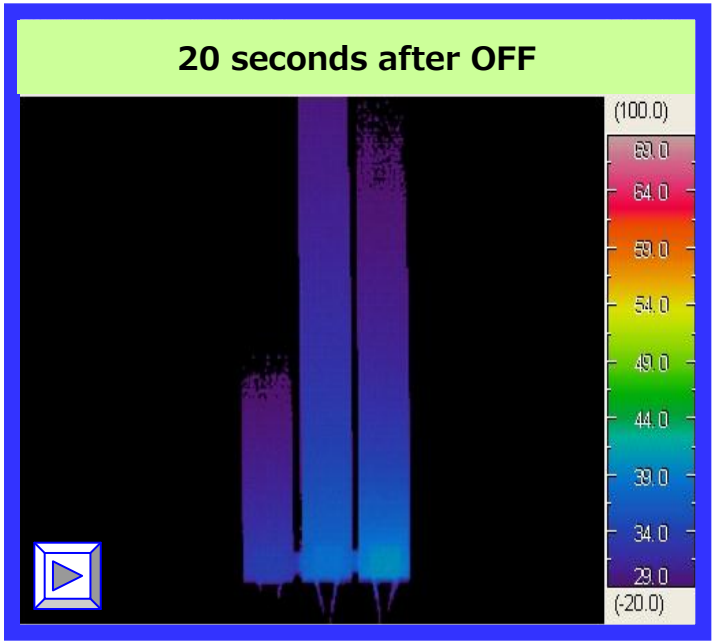
«Heat conductivity when the heater turns on.»



PGS Cu Al

PGS Graphite Sheet carries the heat rapidly due to high heat conductivity

« Cooling state when the heater turns off »



PGS Cu Al

PGS Graphite sheet has high cooling effect .

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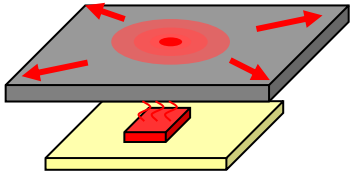
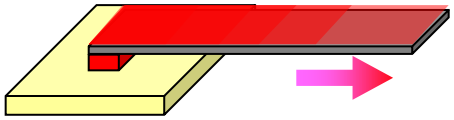
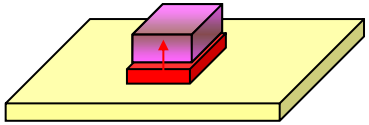
Thermal solution : Product suggestion

Tell us your concern related to heat.

We will propose a suitable solution with our products.

<Customer needs>	<Resolutions>	<Suggested product>
◇ **Lower the surface temperature** Irregular color on LCD display Low temperature burn.	 Thermal diffusion Heat insulation	・PGS (Thermal spreader) 10um-40um thickness with adhesive layer
◇ **Lower the temperature of component parts.** PA, Sensor, etc.	 Heat transport	・PGS (Thermal transfer) 40-100um thickness with adhesive layer with PET isolation tape
◇ **Maximum usage of CPU performance**	 Heat reduction	・PGS (Thermal interface) 70-100um thickness

Feel free to inquire about various selections of our product.

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Application example of PGS Graphite sheet

◆Smart Phone

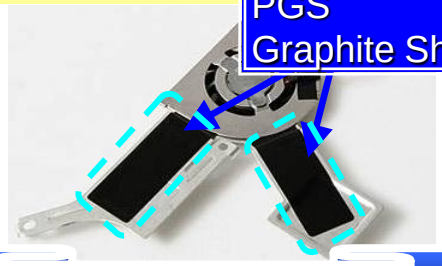
PGS Location: On the Aluminum board which connects CPU and LCD.

PGS Graphite Sheet

High performance Cooling Efficiency

◆Note book PC,Tablet

PGS Location: On the Aluminum board which connects CPU and cooling fan.

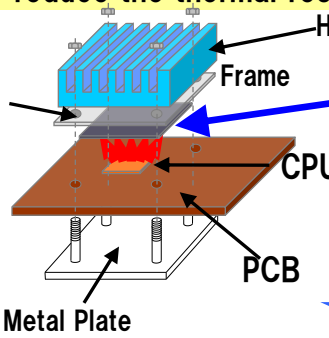


PGS Graphite Sheet

Light ,Cooling efficiency

◆CPU (Server)

PGS® Location :Between CPU and Heat Sink to reduce the thermal resistance and diffuse the heat spot



PGS Graphite Sheet

Silicon Grease

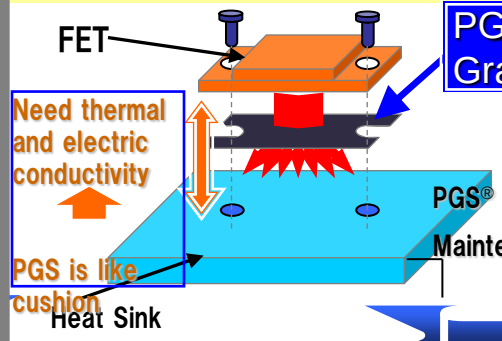
every 3-5 years need to maintenance

PGS® maintenance free

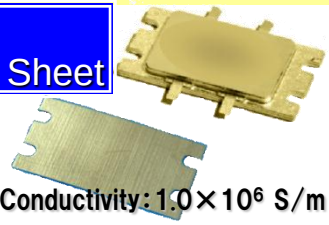
Saving Energy •High Reliability

◆FET (Base Station)

PGS Location: Between FET and Heat Sink to reduce the thermal resistance and diffuse the heat



PGS Graphite Sheet



PGS® Electric Conductivity: 1.0×10^{6} S/m

Maintenance Free

Saving Energy •High Reliability

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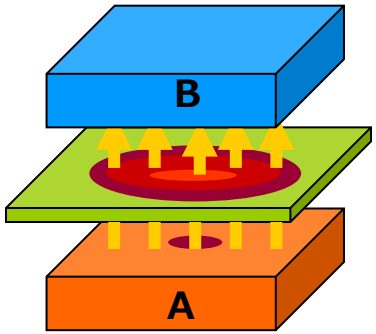
How to use a PGS Graphite sheet

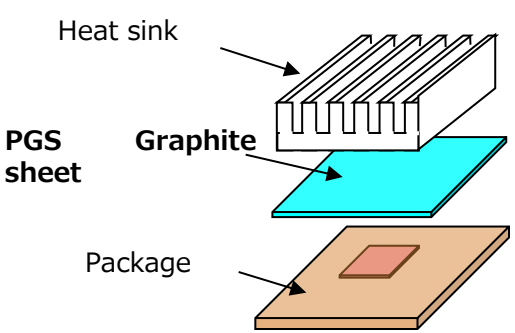
PGS Graphite sheet basic function to conveys heat(Z-direction)

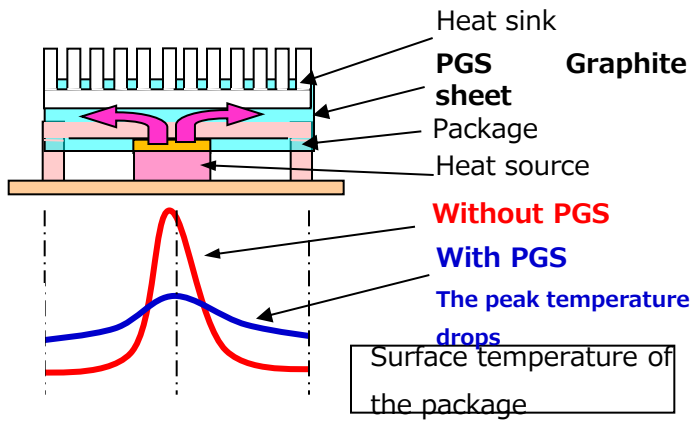
Thermal Interface

Decreasing the thermal resistance and diffusing the heat



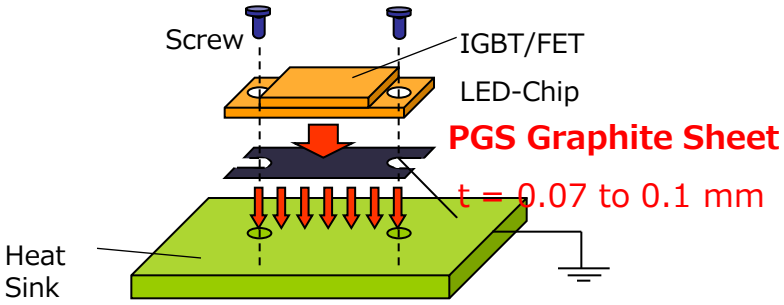
Z direction & X-Y direction



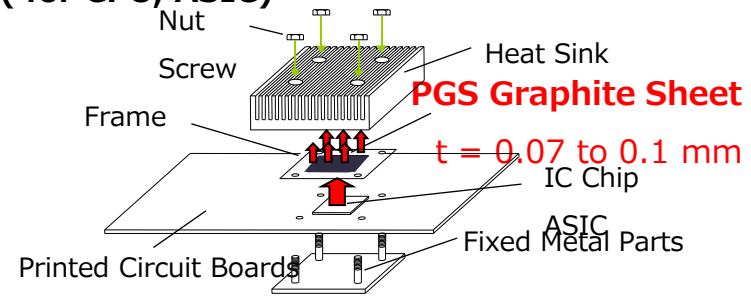


PGS reduces the thermal contact resistance, and soaking

(for IGBT/FET LED Chip)



(for CPU, ASIC)



You can use the heat sink efficiently

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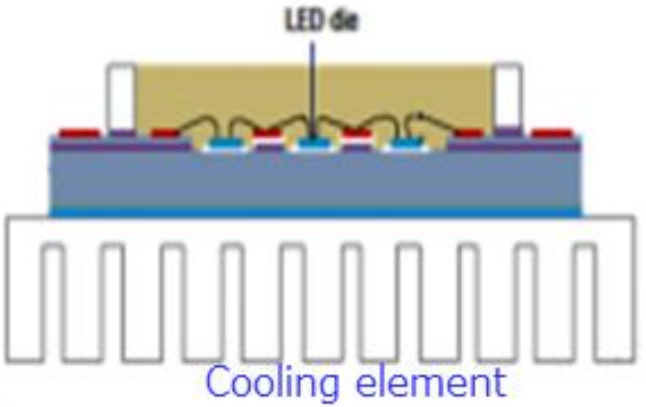
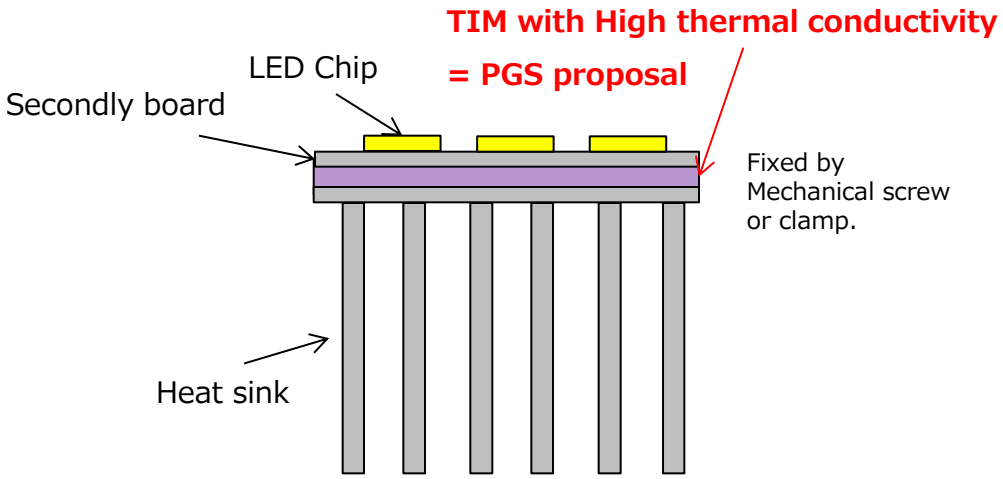
Application example of PGS (LED)

Install between metal board and heat sink

LED module example





PGS proposal

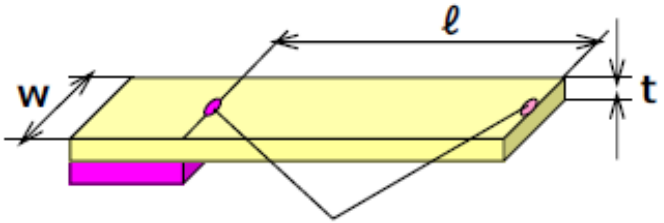
- **PGS 70um or 100um(softer)**
- **Graphite-PAD (under development)**

PGS Graphite Line UP

PGS		10 μm	17 μm	25 μm	40 μm	50 μm	70 μm	100 μm
Thickness (mm)		0.010±0.002	0.017±0.005	0.025±0.010	0.040±0.012	0.050±0.015	0.070±0.015	0.100±0.030
Thermal Conductivity (W/(mK))	X-Y direction	1950 (1800 to 2000)	1850 (1700 to 1900)	1600 (1500 to 1700)	1350 (1250 to 1450)	1300 (1200 to 1400)	1000 (900 to 1100)	700 (600 to 800)
	Z direction	(10)	(11)	(18)	(20)	(20)	(20)	(26)
Thermal diffusivity(cm^2/s)		10 to 12 (0.001 ~ 0.0012 m^2/s)	10 to 11 (0.001 ~ 0.0011 m^2/s)	9 to 10 (0.0009 ~ 0.001 m^2/s)	9 to 10 (0.0009 ~ 0.001 m^2/s)	8 to 10 (0.0008 ~ 0.001 m^2/s)	8 to 10 (0.0008 ~ 0.001 m^2/s)	8 to 10 (0.0008 ~ 0.001 m^2/s)
Density (g/cm^3)		2.13 (2130 kg/m^3)	2.10 (2100 kg/m^3)	1.95 (1950 kg/m^3)	1.80 (1800 kg/m^3)	1.70 (1700 kg/m^3)	1.21 (1210 kg/m^3)	0.85 (850 kg/m^3)
Specific Heat (at 50 ℃)(J/gK)		0.85 (850 J/kgK)	0.85 (850 J/kgK)	0.85 (850 J/kgK)	0.85 (850 J/kgK)	0.85 (850 J/kgK)	0.85 (850 J/kgK)	0.85 (850 J/kgK)
Heat resistance (℃)		400	400	400	400	400	400	400
Extensional strength (MPa)	X-Y direction	40	40	30	25	20	20	20
	Z direction	0.1	0.1	0.1	0.4	0.4	0.4	0.4
Electric Conductivity (S/cm)		20000 (2.0×10^6 S/m)	20000 (2.0×10^6 S/m)	20000 (2.0×10^6 S/m)	10000 (1.0×10^6 S/m)	10000 (1.0×10^6 S/m)	10000 (1.0×10^6 S/m)	10000 (1.0×10^6 S/m)

Support by variety of thickness from 10um – 100um
Suite for X-Y direction by thinner type, Z-dir. by Thicker type.

Thermal transport capability



Temperature difference ⊿T

$$\text{Thermal transport amount (W)} = \text{Thermal conductivity [}\lambda\text{] (W/mK)} \times \frac{\text{Cross section area [t x w] (m2)}}{\text{Length [}\ell\text{] (m)}} \times \text{Temperature difference [}\Delta T\text{] (K)}$$

C (constant)

Parts width, length and temperature difference stay constant, define the C (constant)

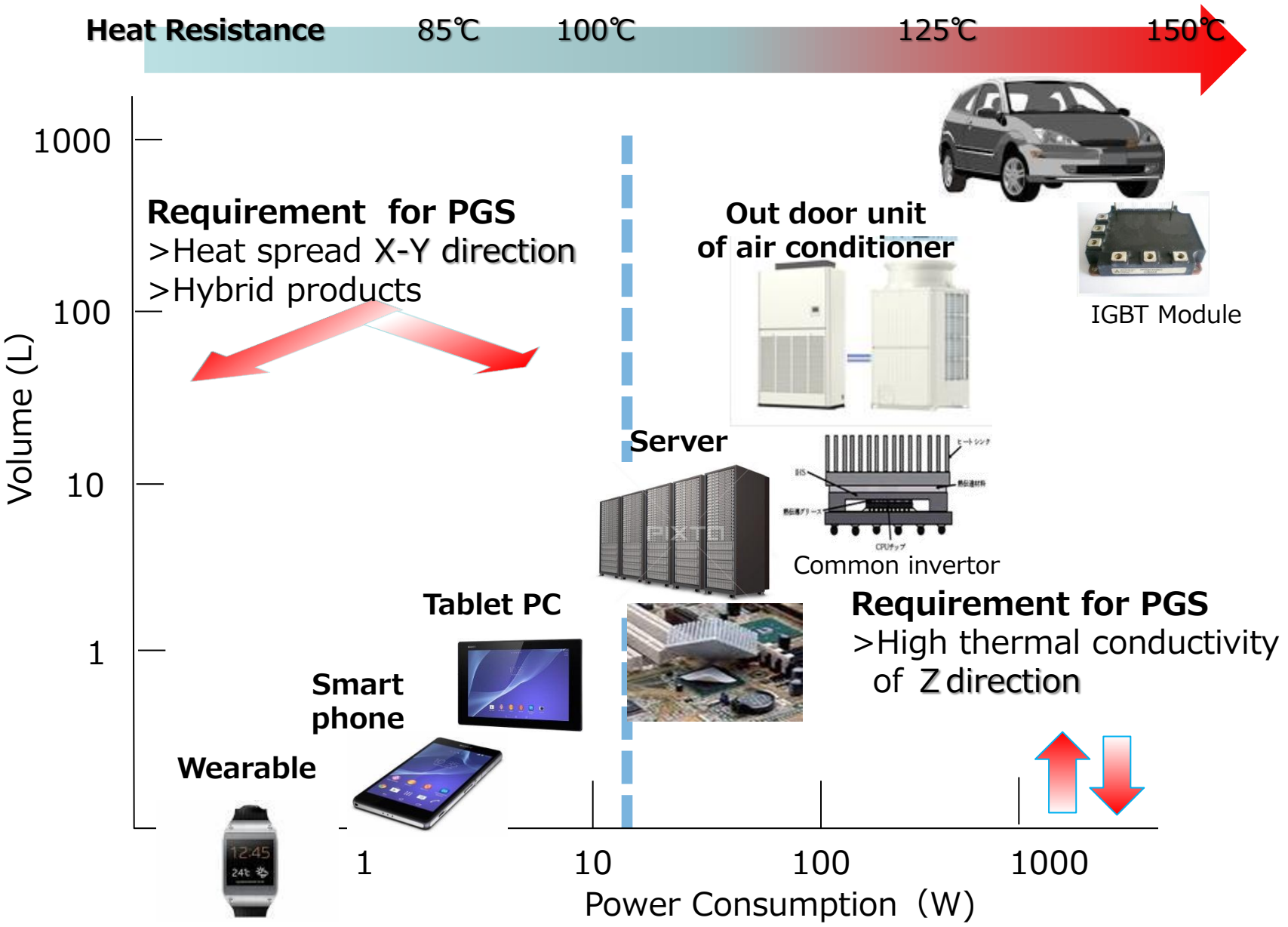
$$\text{C (constant)} = \frac{w\ (m2)}{\ell\ (m)} \times \Delta T$$

To facilitate considering the thermal transport amount, set up the thermal transport coefficient

$$\text{Thermal transport coefficient} = \text{Thermal conductivity [}\lambda\text{] (W/mK)} \times \text{Thickness [t]}$$

Item	Thermal Transport Coefficient	Item	Thermal Transport Coefficient
PGS 10 μm	1950 x 10 = 19,500	PGS 17 μm x 2layers	1850 x 34 = 62,900
PGS 17 μm	1850 x 17 = 31,450	PGS 25 μm x 2layers	1600 x 50 = 80,000
PGS 25 μm	1600 x 25 = 40,000	Cu foil 200μm	400 x 200 = 80,000
PGS 40 μm	1350 x 40 = 54,000	Al foil 200μm	200 x 200 = 40,000
PGS 50 μm	1300 x 50 = 67,500	Mg alloy 200μm	80 x 200 = 16,000
PGS 70 μm	1000 x 70 = 70,000	SUS 304 200μm	16 x 200 = 3,200
PGS 100 μm	700 x 100 = 70,000		

Power consumption and Market requirement for PGS



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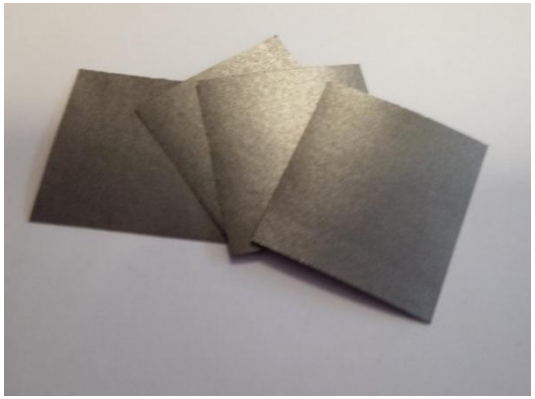
LDPGS

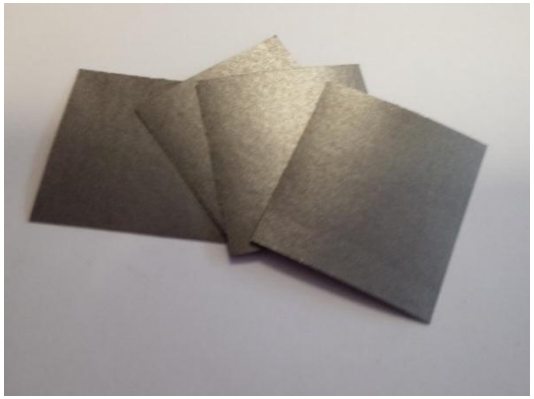
Low Density PGS

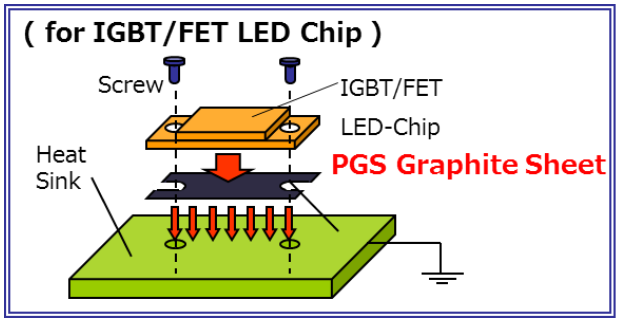
Under Development



What's LDPGS (Low density pyrolytic graphite sheet)?

-LDPGS is artificial graphite that has been developed for TIM（Thermal Interface Material).
-It is possible to lower the thermal resistance of more than grease .
And it enables high reliability and easy handling as compared to grease.





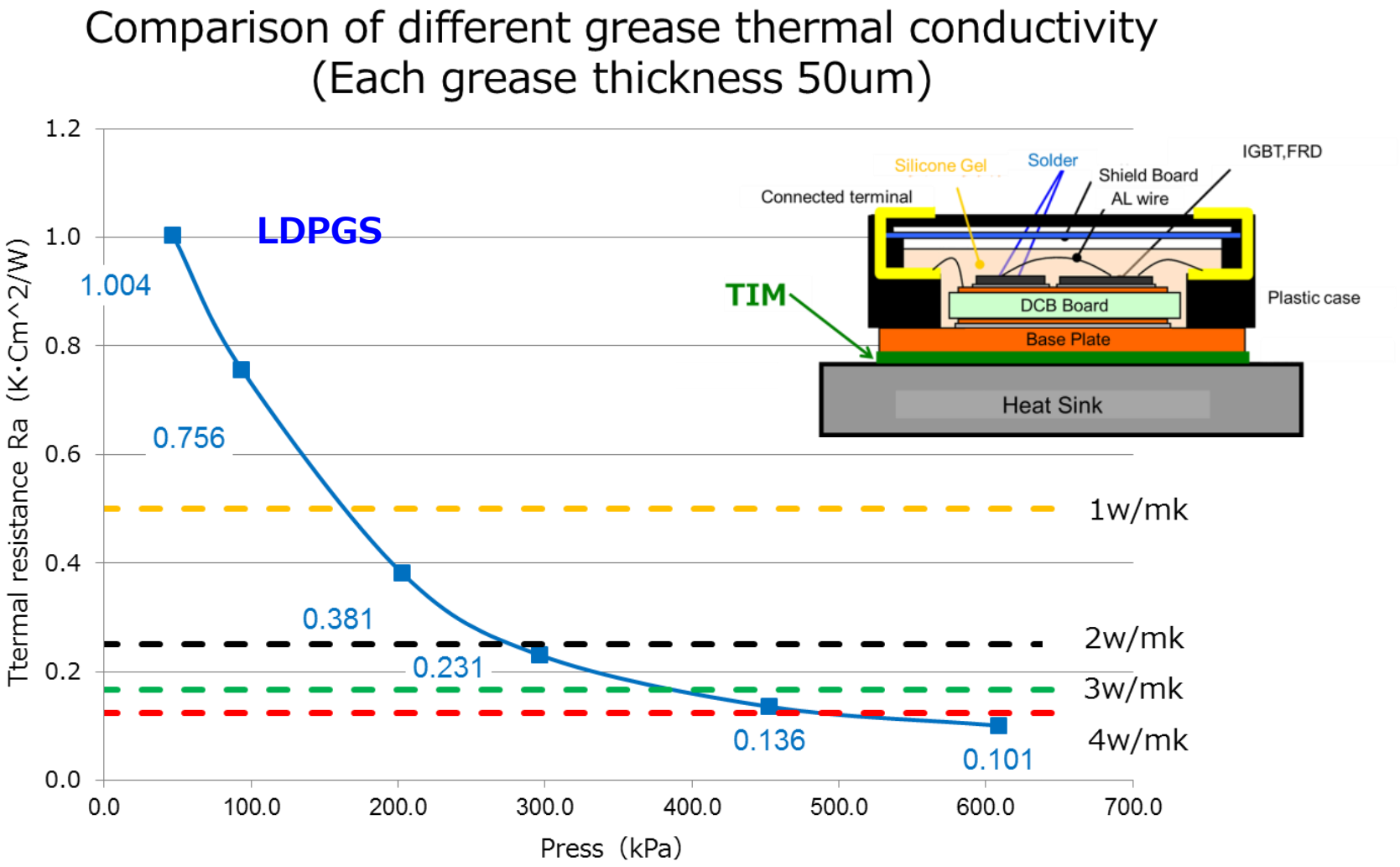
Under Development

MP : Q1 / 2016

Characteristics	unit		Graphite PAD2 (SoftPGS) 0.2mm
Compressibility	%	ASTM D5470 0.5MPa	50
Thermal Resistance	K･cm2/w	ASTM D5470 0.5MPa	0.136
Electrical conductivity	(s/cm)		10000
Thermal Conductivity	w/mk	ASTM D5470 0.1MPa	Z:30
Operation Temperature	degC		-55 to +400
Flame Rating	UL 94		V-0
Thickness	mm		*0.2

Benefit and application of LDPGS 1

-Thermal resistance data



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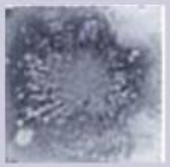
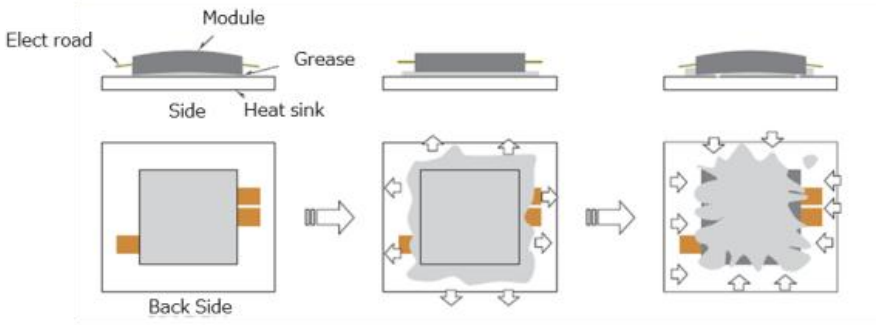
Benefit and application of LDPGS 2

Stable Reliability

Pomp out Test

Heat cycle (-40⇔100degC)

	Initial	120times
Grease		
Soft PGS		



Easy Handling

In the case of Grease

Coating process

Reduce Thermal Stress -> Long life & Robust Applications!

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Graphite-PAD

High thermal conductivity Toward thickness direction (Z-axis direction)

Under Development

What's Graphite PAD

■Characteristics

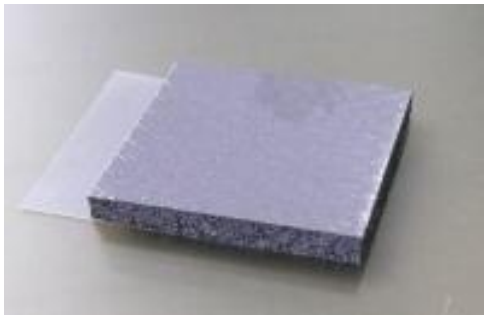
Graphite-PAD is a high-quality thermal interface material(TIM), which has high thermal conductivity and excellent flexibility (deforms easily under low-load condition).
The Graphite-PAD would make it easy to take thermal solutions.

・We have improved thermal conductivity toward thickness direction(Z-axis direction) by filling PGS graphite sheets having high thermal conductivity into silicon resin.

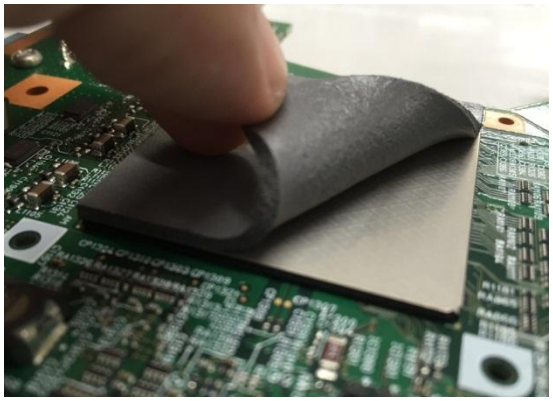
・The excellent flexibility would make it easy to design.

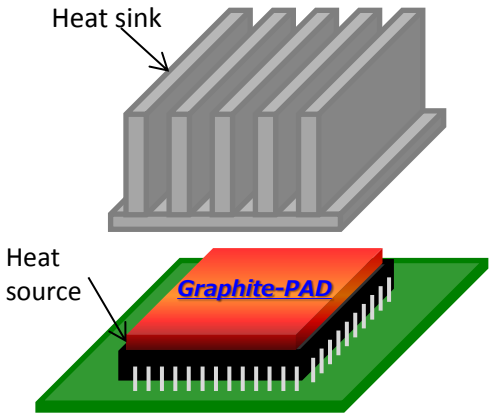
■Development plan

- We are planning to start mass production in FY2015



Case Example





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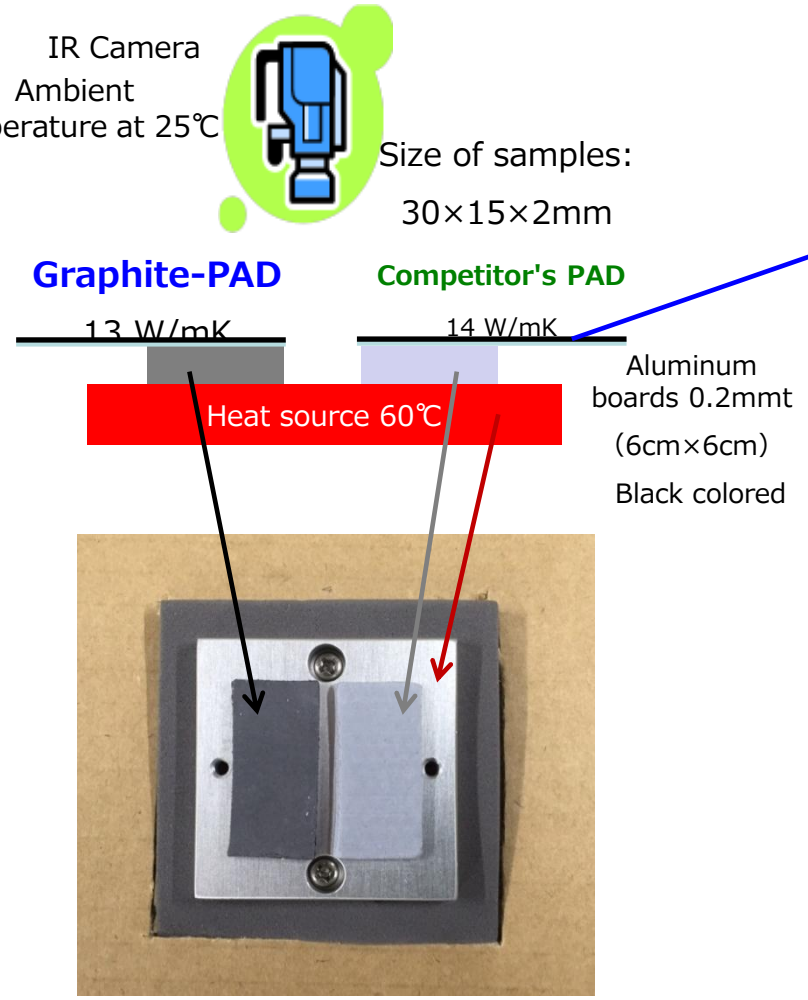
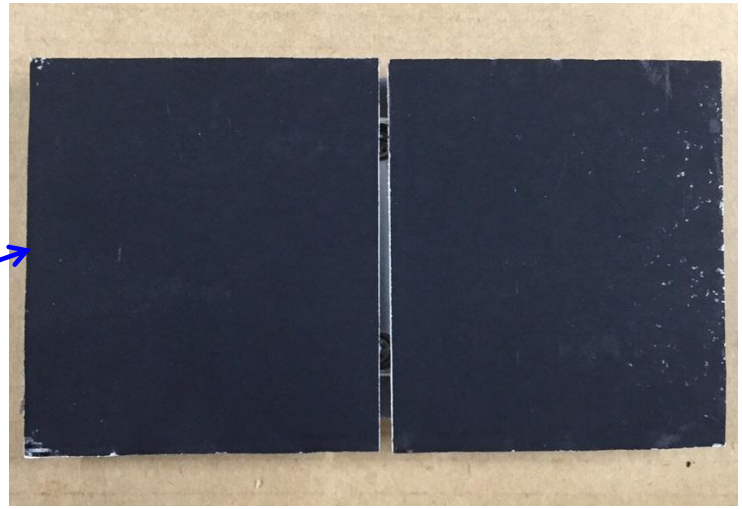
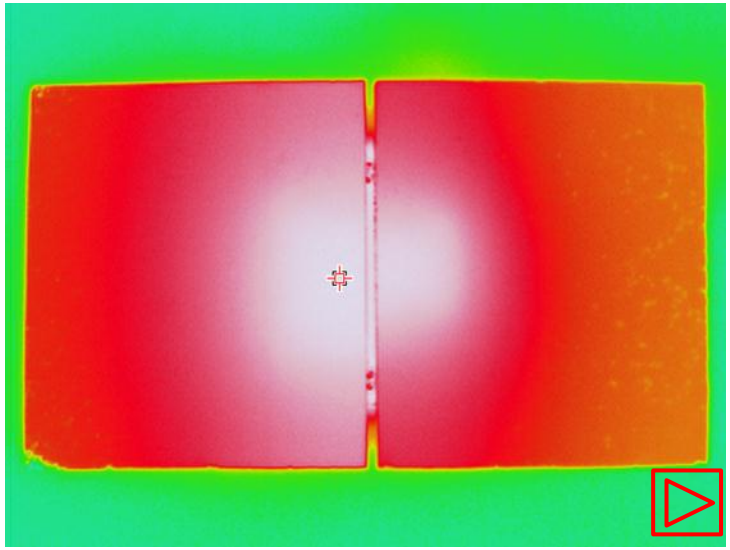
Graphite PAD performance

☐ **Place each components (Graphite-PAD and competitor's PAD) between the heat source and aluminum boards and observe them with a thermograph.**







Graphite-PAD　　Competitor's PAD

- Graphite-PAD transfers heat quickly due to its high thermal conductivity.

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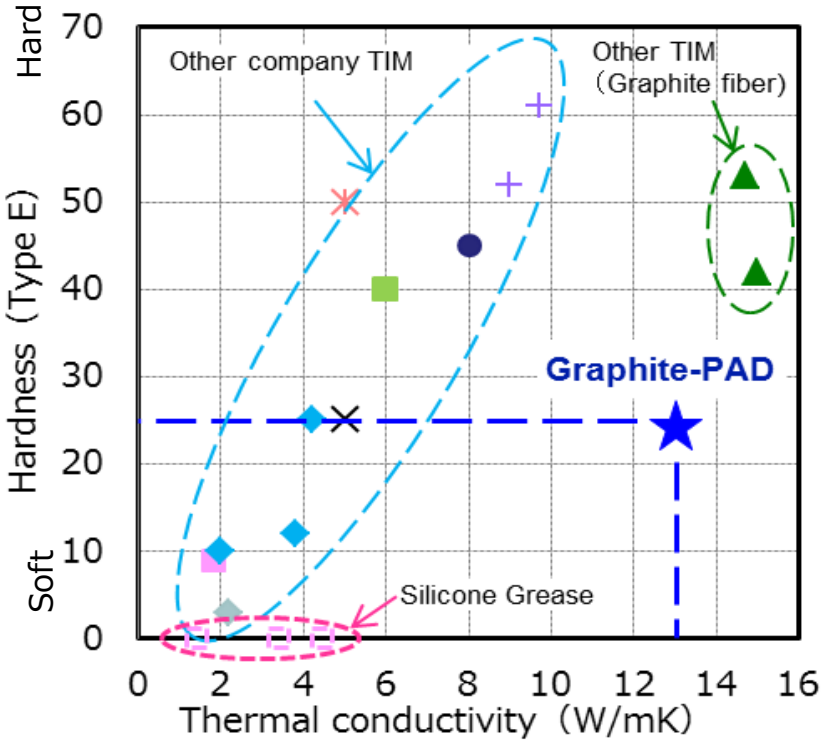
Relationship thickness and TIM

- Hardness
- Compressibility

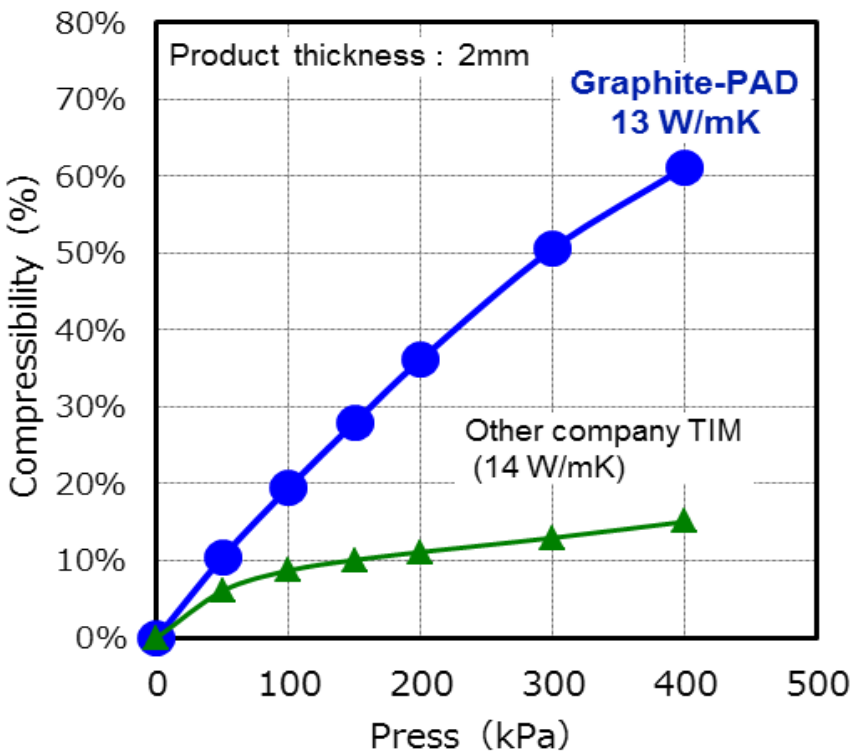
→

- Balance with High Thermal conductivity
- Performance increase after compressibility

Hardness VS Thermal conductivity



Compressibility



※ Thermal conductivity :TIM Tester (ASTMD5470)

Graphite-PAD is Good balance of High thermal conductivity and Hardness

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Graphite PAD Characteristics

Characteristics	unit		Graphite PAD1 2.0mm
Hardness	shoa 00	ASTM D2240	50
Volume Resistance	ohm cm		$4 X10^{5}$
Breakdown Voltage	AC kV/mm		-
Thermal Conductivity	w/mk	ASTM D5470 50kPa	Z:13
Operation Temperature	degC		-45 to +150 (200)
Flame Rating	UL 94		V-1
Thickness	mm		*0.5 to 3.0

Under Development

MP : Q1 / 2016

Thermal solution offer

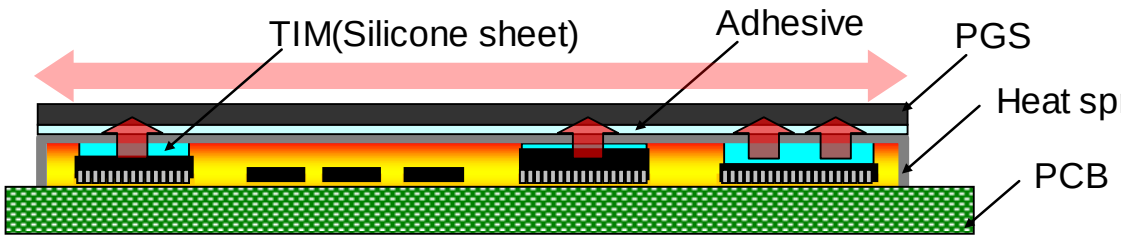
Squeezing heat out of PCB

SSM -Semi Sealing Material

(PGS with Easy-sealing material)

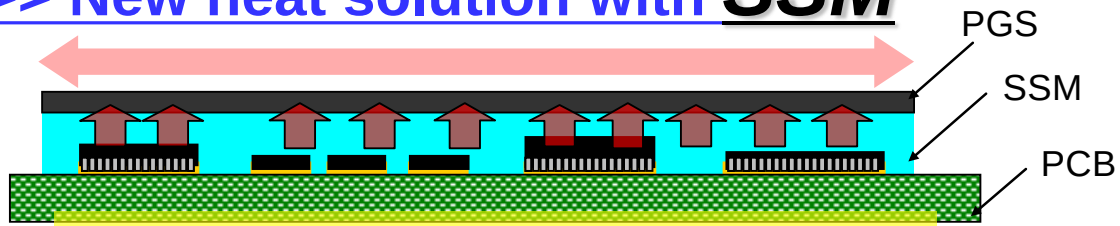
Function of SSM

>> Example of current heat solution



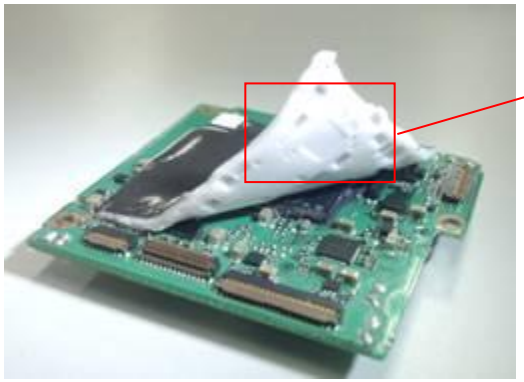
- TIM's(Thermal Interface Material) are put just on the semi-conductors
- PGS spreads out the heat

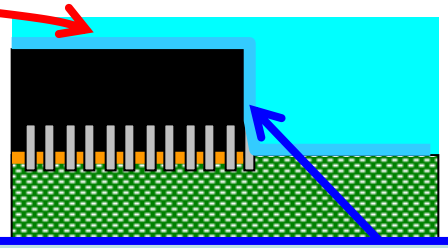
>> New heat solution with ***SSM***



Squeeze & Spread the heat!!

- SSM can covey whole PCB and transport the heat from ICs to PGS effectively





SSM is thermoplastic resin with thermal conductivity material.
Therefore, contact thermal resistance is very low.
Non-siloxane gasification sheet due to non-use of silicone material.

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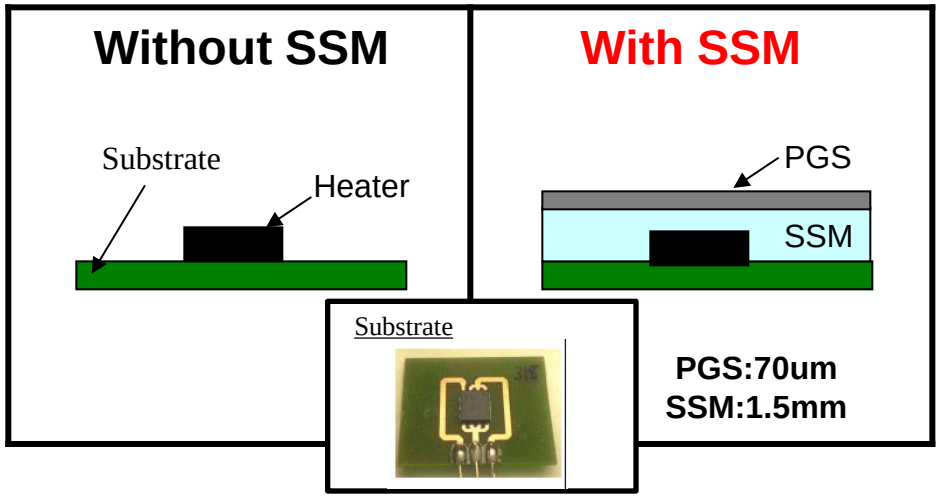
Thermal verification data of SSM

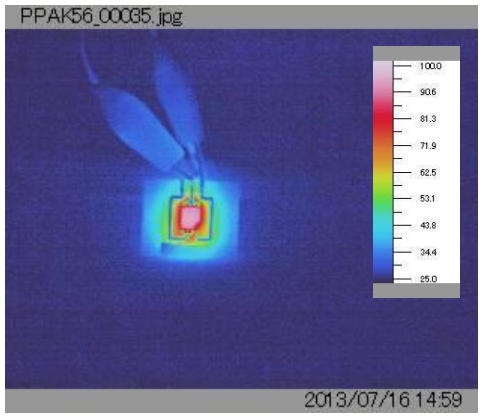
➢ **Test samples**

Substrate	dimension	25.4*20.0mm
	thickness	1.0mm
	material	FR-4
Heater	dimension	5.15*6.15mm
	Thickness	1.0mm



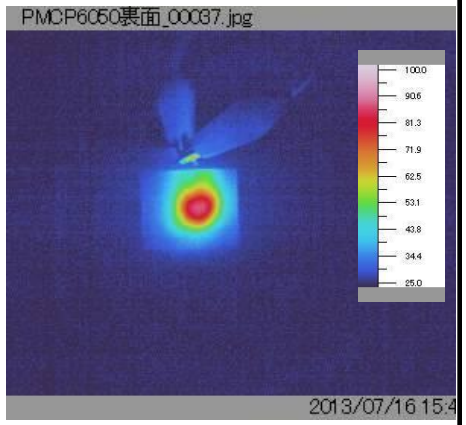
Without SSM

Front side



96degC

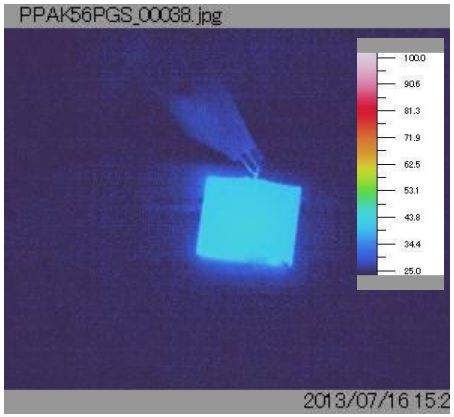
Back side



95degC

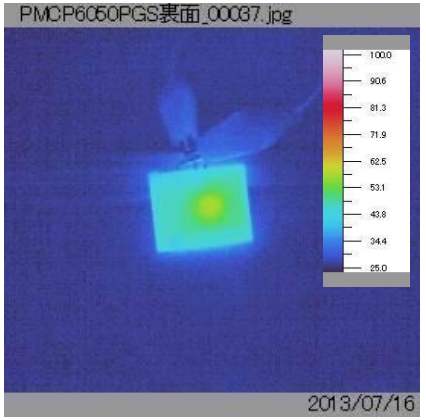
With SSM

Front side



46.5degC

Back side



53.5degC

SSM can carry the heat from Heater to PGS and reduce heater temperature

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Usage example of SSM

IPM (Intelligent Power Module)

IPM : 6 MOSFET .

The 6 MOSFET are heat sources.

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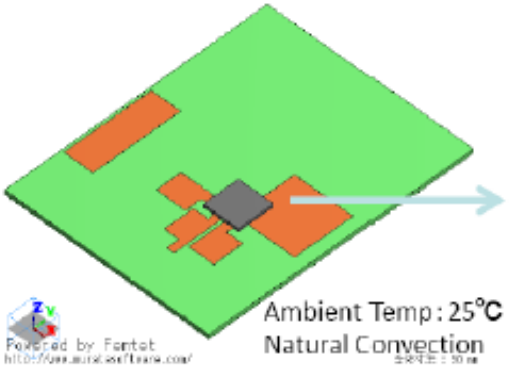
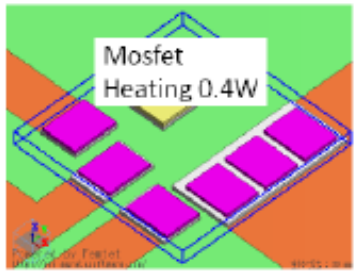
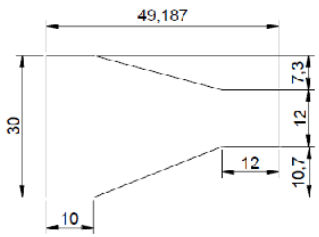
SSM thermal simulation

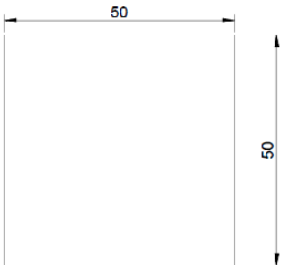
International Rectifier
PGS Thermal Solution Simulation

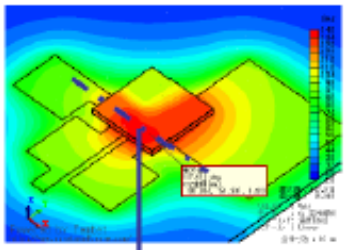
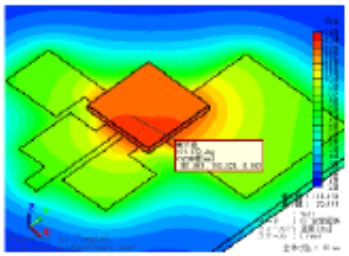
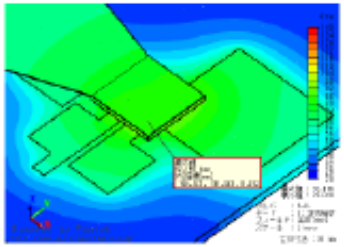
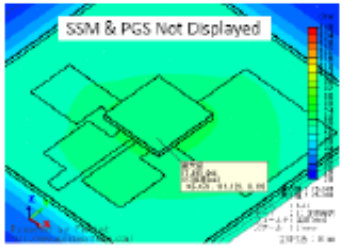
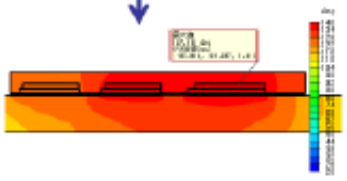
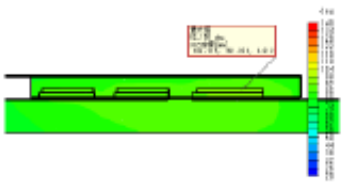
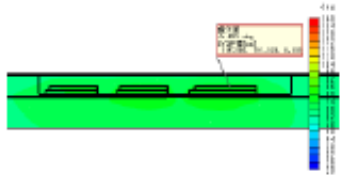
2014.12.11









	No Thermal Solution (Control)	Solution ① 70um PGS on IPM Surface	Solution ② 70um PGS Heat Pipe	Solution ③ SSM＋70um PGS
Temp Distribution				
Temp Distribution (Cross Section)				
Max. Temp	137℃	132℃	92℃	76℃

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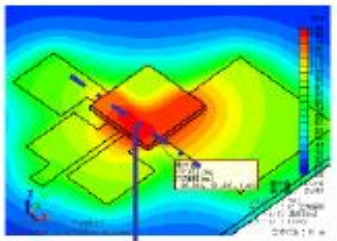
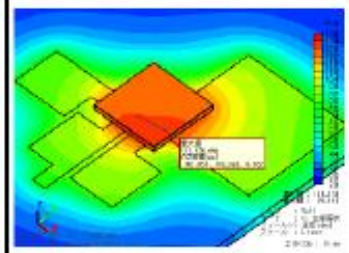
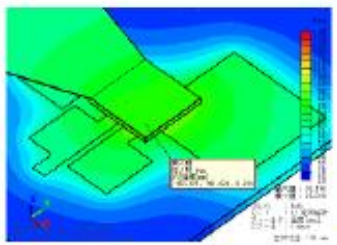
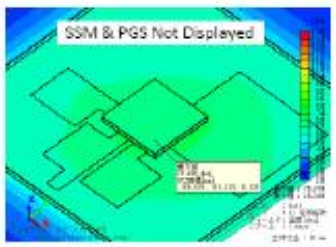
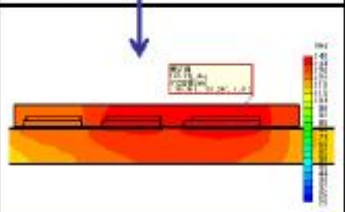
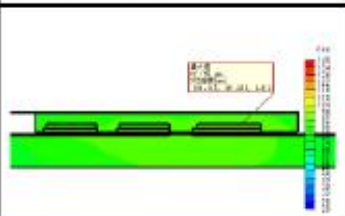
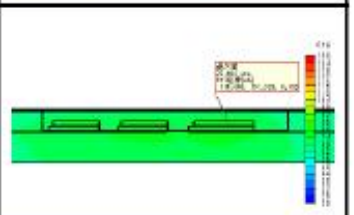
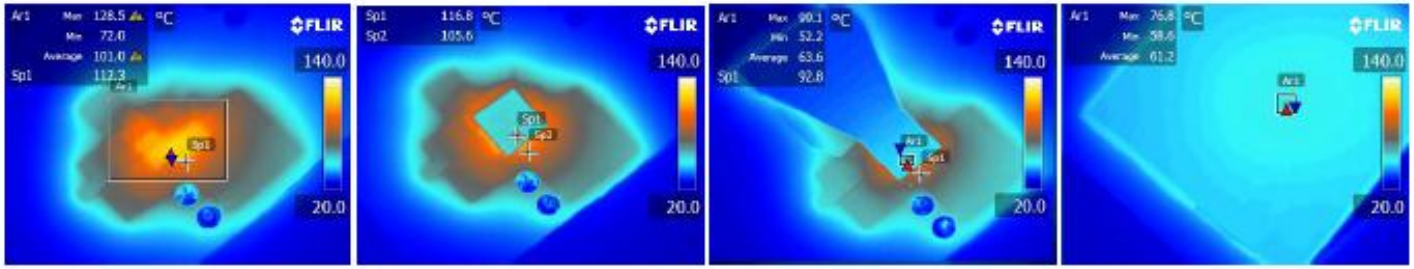
Thermal verification of simulation data

	No Thermal Solution (Control)	Solution ① 70um PGS on IPM Surface	Solution ② 70um PGS Heat Pipe	Solution ③ SSM＋70um PGS
Temp Distribution				
Temp Distribution (Cross Section)				
Max. Temp	137℃	132℃	92℃	76℃

Actual measured Data



$T_{SURFACE,MAX}$	129°C	117°C	99°C	77°C
T_{PCB_V+}	112°C	106°C	93°C	75℃
		EYG-A091207M PGS + Adhesive Tape	EYG-A091207M PGS + Adhesive Tape	SSM/PGS 2.0mm/70μm

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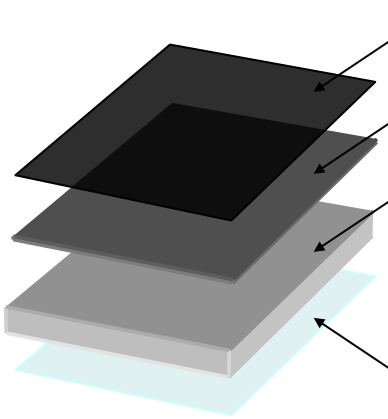
SSM – Semi Sealing Material P/N

>> Structure

SSM PGS with Easy-sealing material



None
PET (No adhesive)
Adhesive tape

<Thickness>
100um, 25um
70um, 17um
50um, 10um
40um

<Thickness>
0.5mm, 1.0mm
1.5mm, 2.0mm
3.0mm

Part Numbers: EYGE0912X

Sample size 90mm*115mm

Type of SSM
"X" = Normal

Thickness of PGS	
100um	A
70um	B
50um	C
40um	G
25um	D
17um	E
10um	F

Thickness of SSM	
0.5mm	5
1.0mm	6
1.5mm	7
2.0mm	8
3.0mm	9

PET/Adhesive	
None	-
PET 8um	Q
PET 10um	D
PET 30um	P
Adhesive 6um	F
Adhesive 10um	M
Adhesive 30um	A

NASBIS

(Thermal insulator sheet)

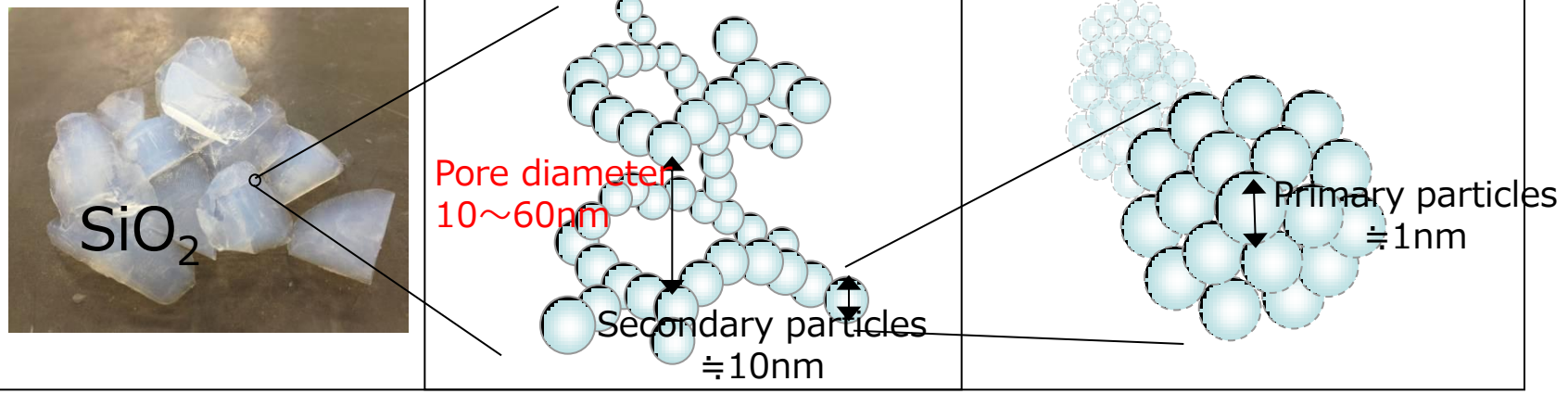
In Mass Production

What's NASBIS

NASBIS = Nano Silica Balloon Insulation Sheet

■ Aerogel structure

Aerogel and fabric composite Insulator



Achieve low thermal conductivity of convection due to pore diameter is smaller than mean free path of air 68nm.

■ Feature of Aerogel

(1) Low thermal conductivity 0.014～0.021W/m·K
(2) Low sound propagation 120m/s
(3) Low bulk density 0.050～0.250g/cm^3
(4) High transparency 90～94%@10mmt
(5) Refractive index like air 1.015～1.055
(6) High porosity 90～98%
(7) Large specific surface area 600～1,000m^2/g

Impregnate Aerogel into fabric

(Typical : 0.020W/mK)

In Mass Production

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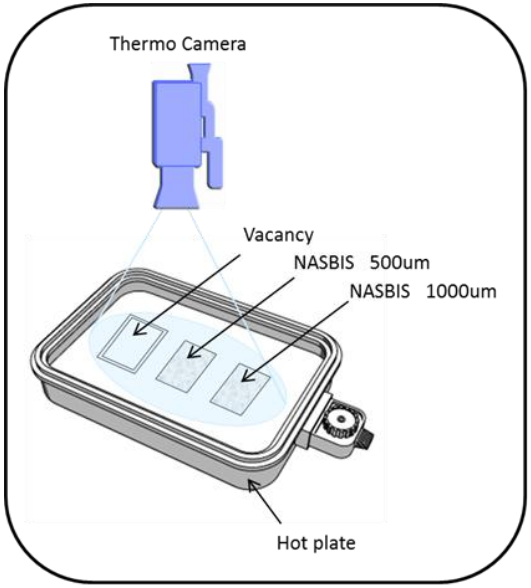
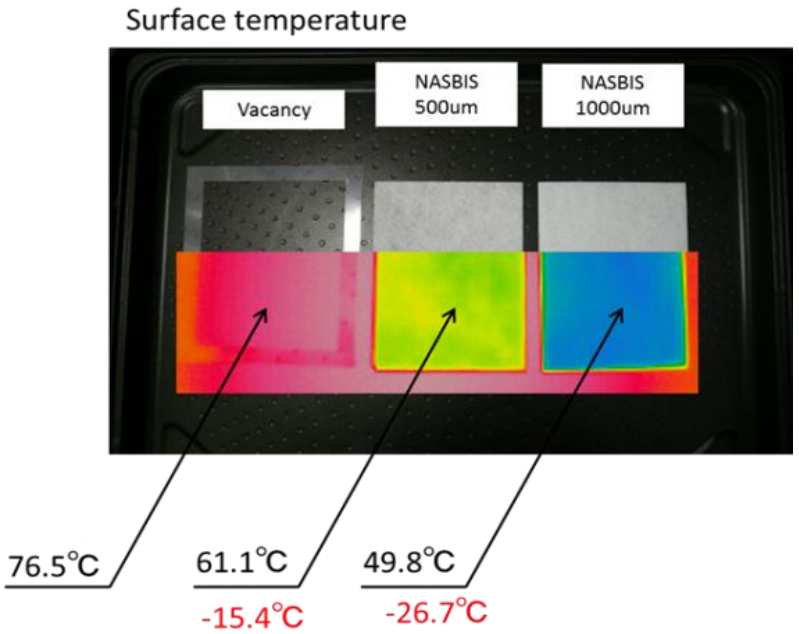
Heat insulation performance of NASBIS

Heat Insulation performance of NASBIS



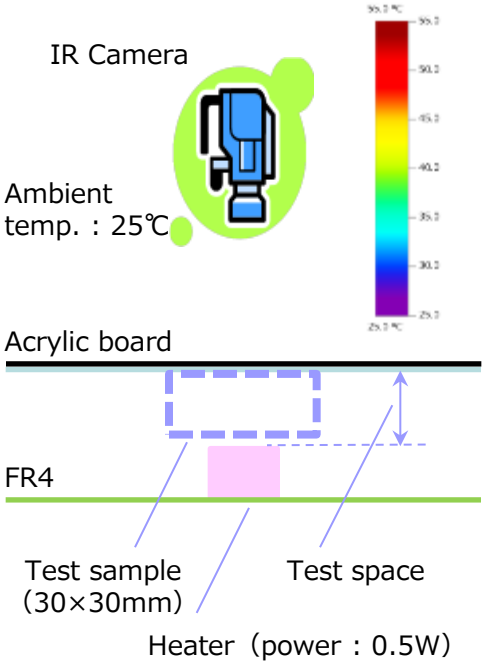


特性	単位	特性値
Operation Temperature	℃	-20 to +100
Thickness	um	50,100,500,1000 *1
Thermal Conductivity*2	W/mK	0.018 to 0.024
寸 法	mm	max 280×400

Data in a table is the measured value. It isn't the specification.

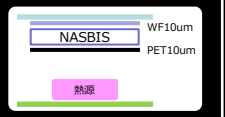
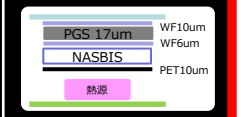
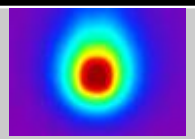
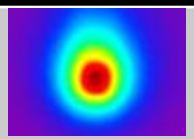
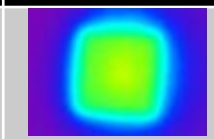
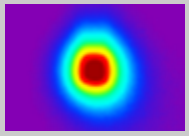
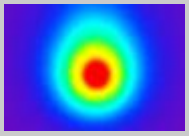
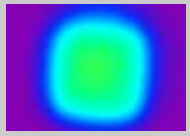
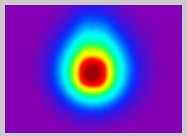
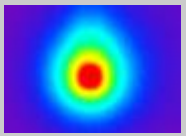
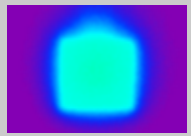
Test Method　Thermal Conductivity ; HFM（NETZSCH, ASTM C 518,ISO 8301,JIS A1412）

Thermal verification of NASBIS



Material	Spec.
Acrylic board	100×100×1.0mm
FR4	100×100×1.5mm
PI tape	W:5mm, T:50um
Heater	10×10×2mm

Insulatied　Relief Heat spot

Thickness of NASBIS ＼ 試料構成		Air	NASBIS	NASBIS＋PGS
				
50um Test space: 100um	Surface temp.(Max) (Difference only air)	 56.1℃	 52.8℃ (⊿ 3.3℃)	 38.0℃ (⊿ 18.1℃)
	Heater temp.	62.9℃	64.3℃	53.0℃
100um Test space: 150um	Surface temp.(Max) (Difference only air)	 55.8℃	 51.9℃ (⊿ 3.9℃)	 36.9℃ (⊿ 18.9℃)
	Heater temp.	62.9℃	64.2℃	54.3℃
500um Test space: 550um	Surface temp.(max) (Difference only air)	 54.3℃	 49.3℃ (⊿ 5.0℃)	 35.0℃ (⊿ 19.3℃)
	Heater temp.	65.6℃	65.4℃	63.9℃

- The good insulation characteristics of NASBIS than Air
- NASBIS is able to cancel a heat spot by an insulation and the composition with the heat spreader.

⇒ **NASBIS makes insulation characteristics in the narrow space and enables relief heat sport**

Panasonic

Thank you

We appreciate your consideration.