Heat Dissipation Structure of PCB for Space Applications

26th June 2024

OKI Circuit Technology Co.,Ltd.

Technology Headquarter
Yasuo Toyokura

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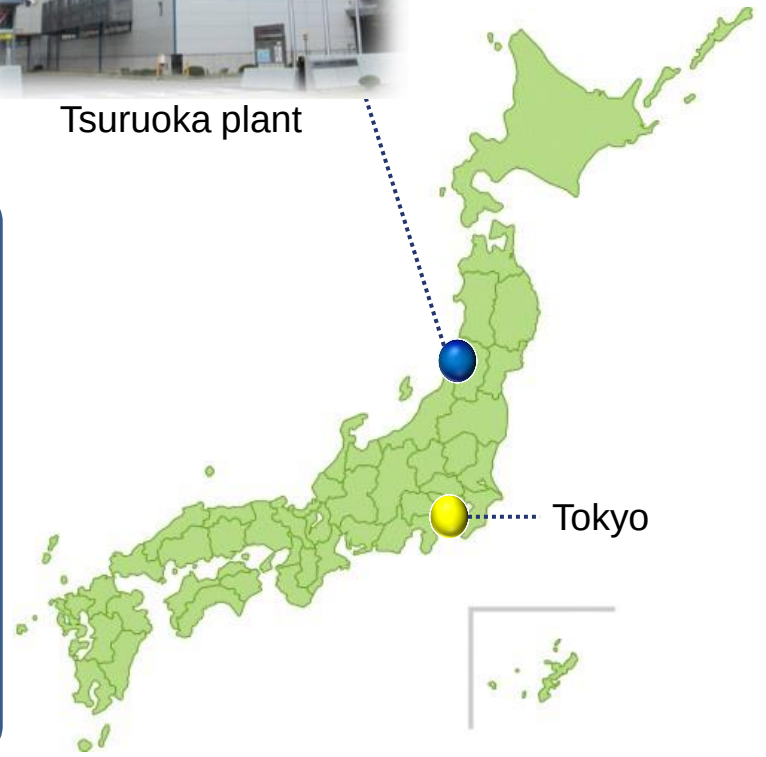
- Company overview
- Current situation of space components
- Manufacturability and reliability
- Effect on heat dissipation (Source from JAXA)
- Conclusion & future plan

Name	**OKI Circuit Technology Co.,Ltd. (OTC)**
Address	**Tsuruoka, Yamagata, Japan**
Established	**1980 (44years)**
Business	**Design, manufacture, assembly and sale of printed circuit boards, electronic devices and electronic components (Main market: Space, Defense)**
Certification	**7 types of JAXA-QTS-2140 (No.1 of Japan)**

JAXA: Japan Aerospace Exploration Agency

Tsuruoka plant



The Shonai Plain is the most suitable region for rice cultivation in Japan.

Sake brewery in Tsuruoka City wins gold medal at 2023 Japanese Sake Competition

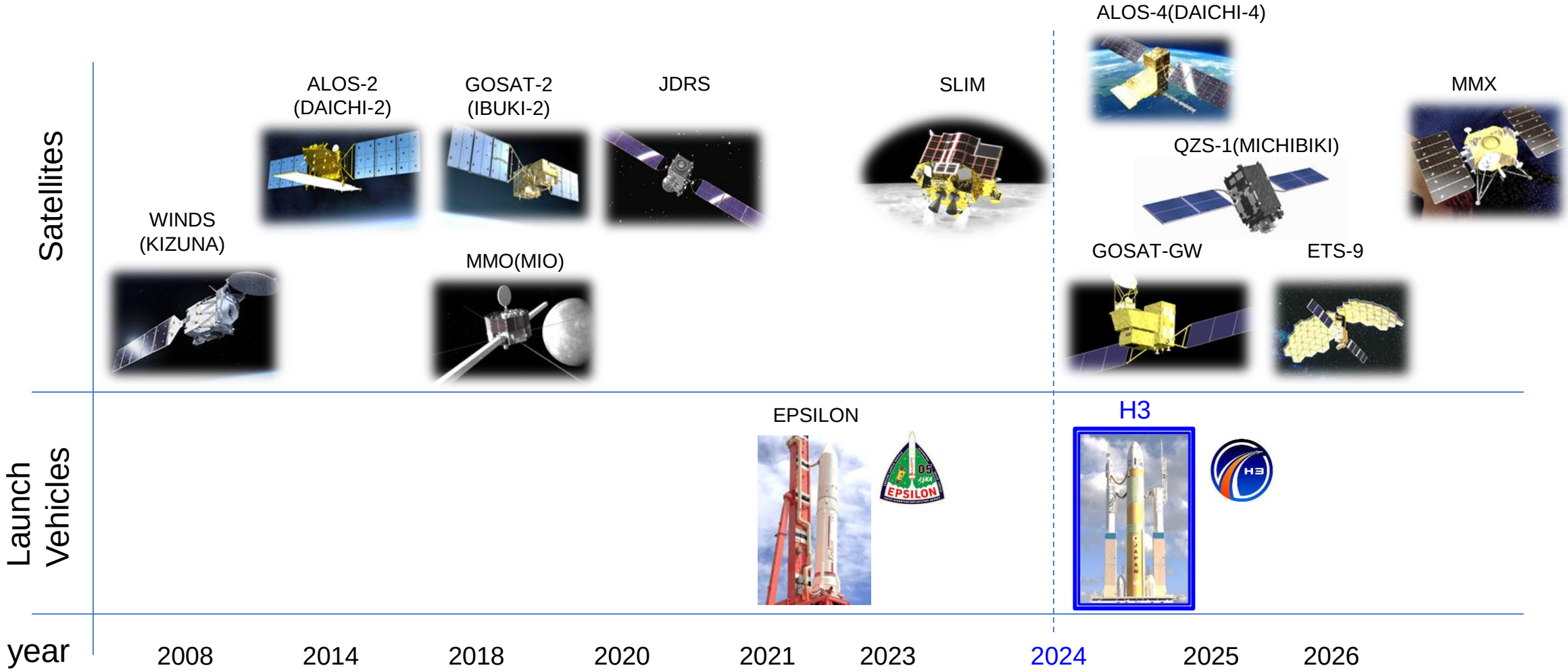
Copyright: DEWAZAKURA SAKE BREWERY

Japanese heritage
Five Storeyed Pagoda on Hagurosan


Copyright: Tsuruoka city

Space market

- We provide PCBs for many satellites and launch vehicles.(2008~2026)



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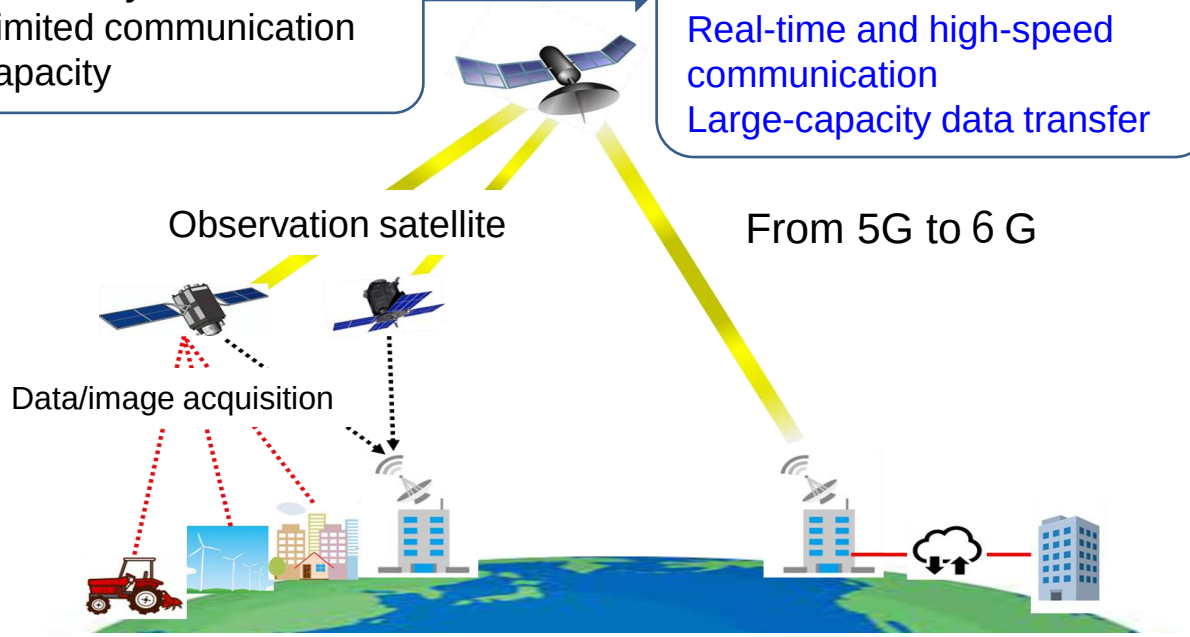
Current situation of space components

- Electrical power consumption will increase due to high speed and larger capacity communication such as 5G and 6G
- As the number of high-performance components increases, electrical power consumption also increases
- For the future, heat dissipation structures for space electric components become increasingly necessary

Increase data capacity of satellites

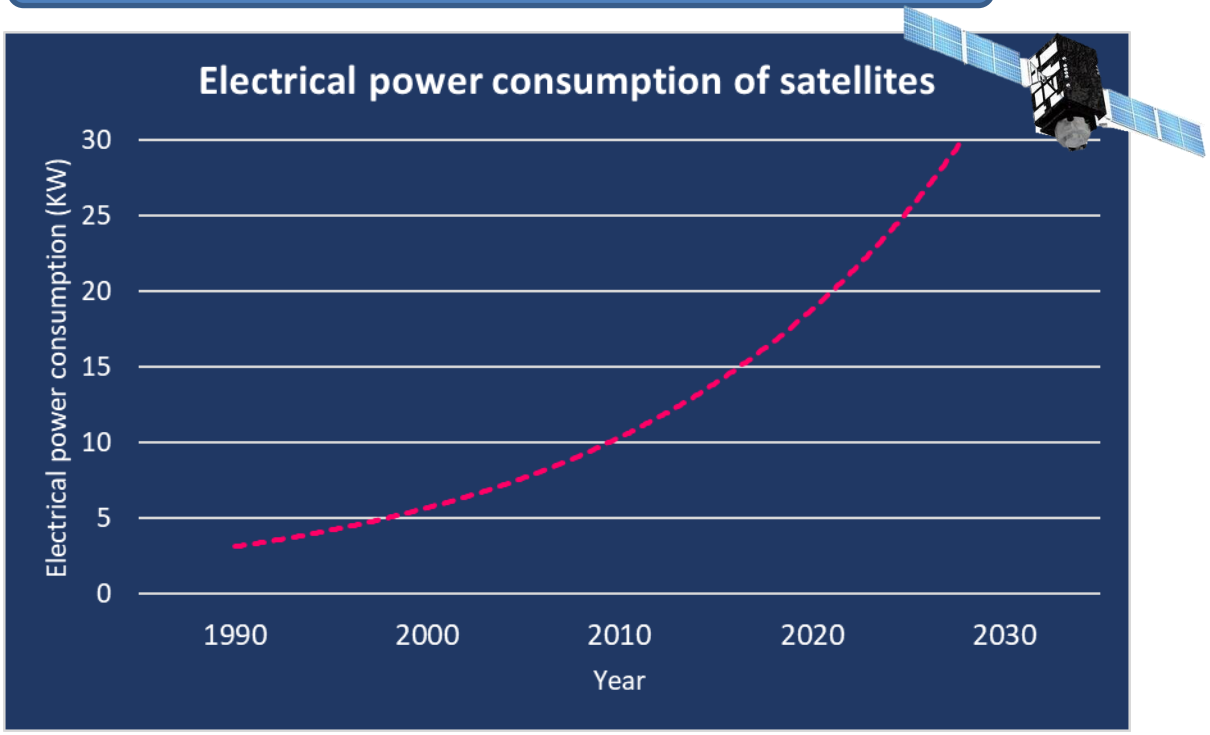
Currently
Limited communication capacity

Future
Real-time and high-speed communication
Large-capacity data transfer



Copyright: OKI Circuit

Transition of electrical power consumption

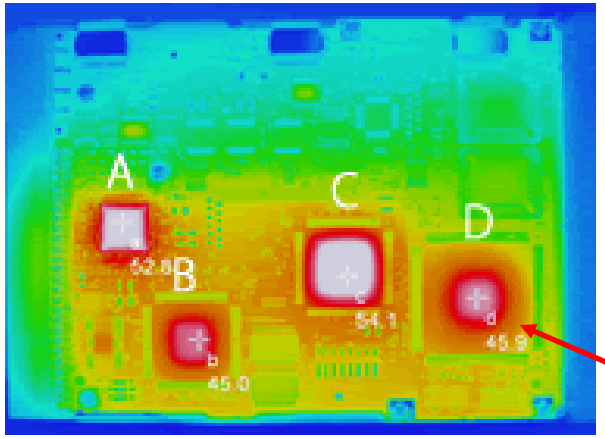


Reference only

Defections of electrical components by generation of heat

- Increasing of electrical power induces generation of heat raising of package components
- Generation of heat of components impacts to transmission delay & defection

Impact due to heat generation



Heat generation of parts

- Performance
  - Transmission delay
  - Performance degradation
- Mechanical
  - Failure due to thermal stress
  - Solder crack at component connections
- Damage
  - Insulation deterioration
  - Deterioration of resin due to heat

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Mechanism of heat dissipation in space applications

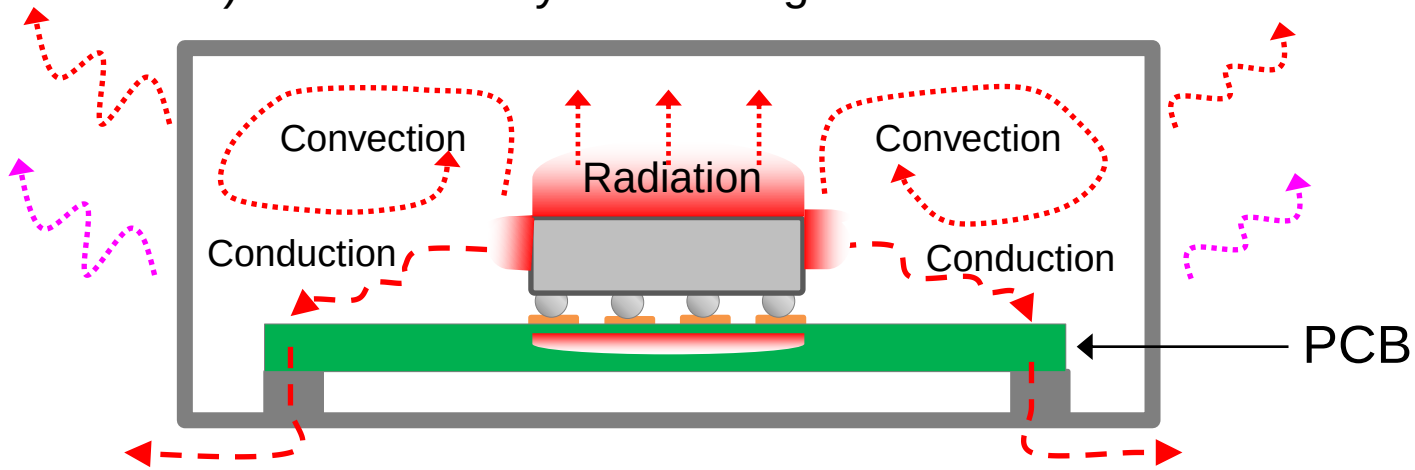
[Examine 3 types of heat transmission]

- Convection (flow of heated gas) cannot be expected in space circumstance
- Conduction (through solid) is more efficient than radiation (electromagnetic wave)

⇩

✓ Arrange materials with high thermal conductivity between electric parts and chassis
✓ Increase materials with higher thermal conductivity to improve heart dissipation efficiency

< 3 types of heat transmission>
1) Conduction – through solid
2) Convection – flow of heated gas or liquid
3) Radiation – by electromagnetic wave



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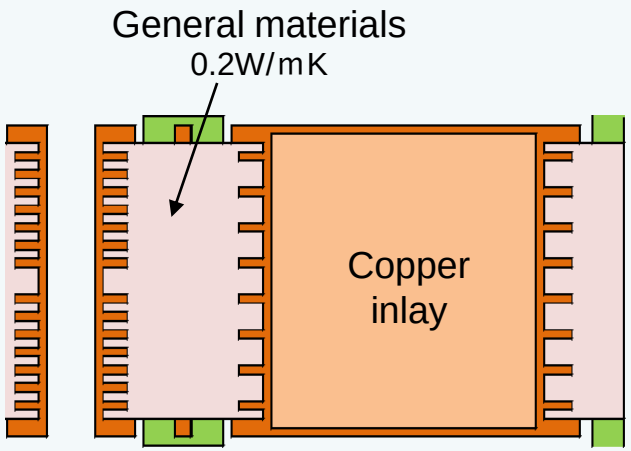
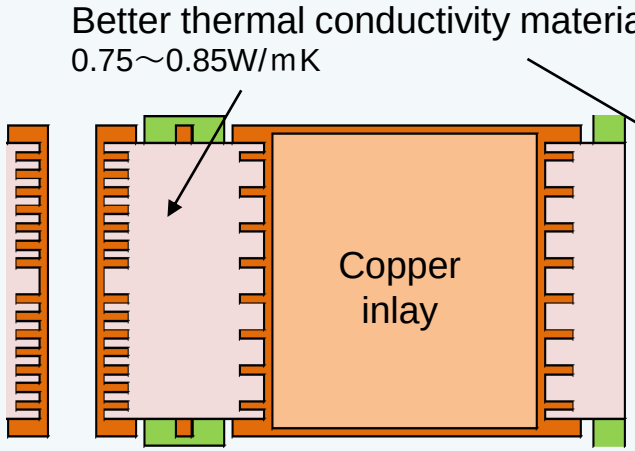
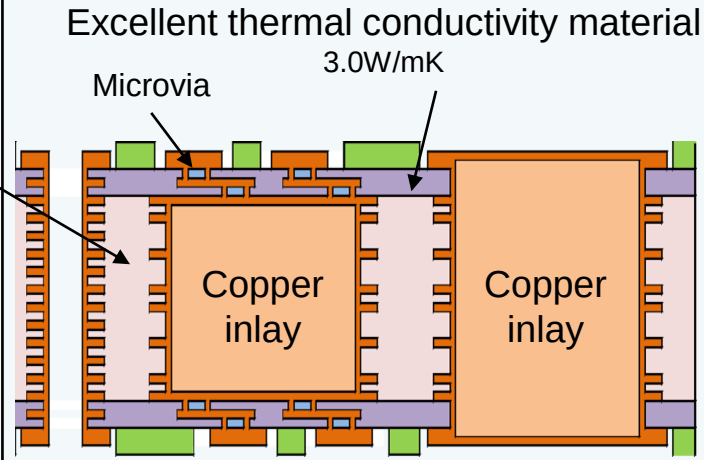
Verification of manufacturability and heat dissipation

We devised 3 structures and verified manufacturability and heat dissipation

CCL: Copper Clad Laminate
PP: Prepreg
SM: Solder mask

		Type 1	Type 2	Type 3
Specifications	Struc-ture	Copper inlay in PTH	Copper inlay in PTH	HDI (2 stages) on copper inlay in buried via
	CCL	General material (Thermal conductivity:0.2W/mK)	Better thermal conductivity material (Thermal conductivity:0.75 to 0.85W/mK)	Better thermal conductivity material (Thermal conductivity:0.75 to 0.85W/mK)
	PP	Same as above	Same as above	Excellent thermal conductivity material for HDI (Thermal conductivity:3.0W/mK)
	SM	General material (Thermal conductivity:0.25W/mK)	Excellent thermal conductivity material (Thermal conductivity:2.0W/mK)	Excellent thermal conductivity material (Thermal conductivity:2.0W/mK)
Structural drawing				

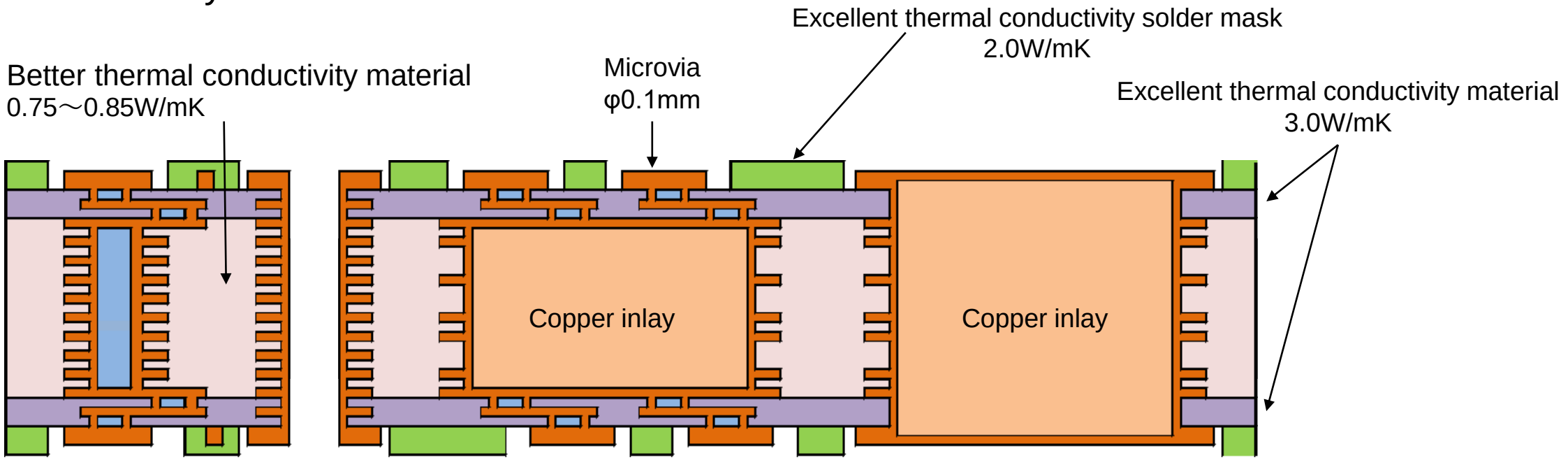
Properties of materials

Structure/Material		Type 1 General Material	Type 2 Better thermal conductivity material	Type 3 Excellent thermal conductivity material	
Laminate materials	Category	Copper clad laminate Prepreg	Copper clad laminate Prepreg	Copper clad laminate Prepreg	Prepreg for HDI layers
	Supplier	Resonac	Resonac	Resonac	RISHO KOGYO
	Model Name	MCL-I-671	MCL-E-679FG	MCL-E-679FG	ES-3245
	Thermal Conductivity (W/mK)	0.20	**0.75-0.85**	**0.75-0.85**	**3.0**
Solder Mask	Supplier	TAIYO INK MFG			
	Model name	PSR-4000	**PSR-4000 HS-2W**		
	Thermal Conductivity (W/mK)	0.25	**2.0**		

Reliability test - specification of type 3 structure

All structures were manufactured without any problems and had heat dissipation properties as expected. Next we performed reliability tests.

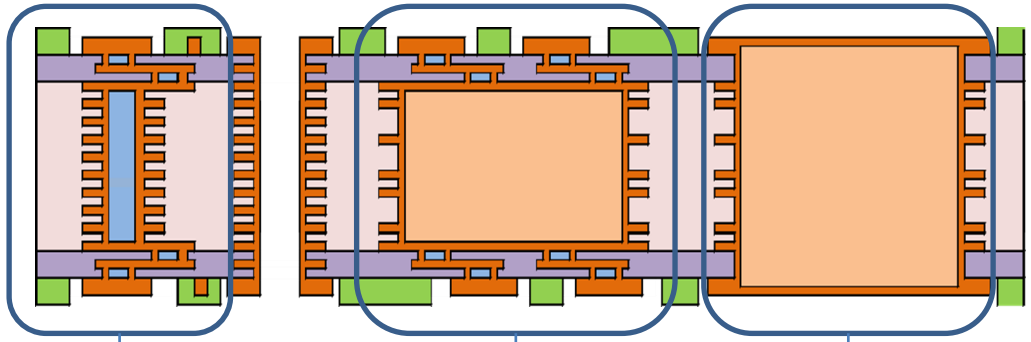
[Specifications of type 3 structure]
Number of layers:14 / Board thickness:2.4mm



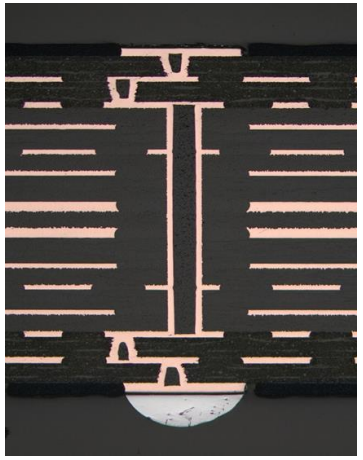
Reliability test result

No.	Item	Test Condition	Method	Result	Judgement
1	Thermal stress	Solder float 288℃x10sec x 3times	Visual	No measling, cracks, and other defects	PASS
2			Microsection	No defects	PASS
3	Thermal cycling	Precondition: Reflow Sim. 3times Min. temp.: -65℃ Max. temp.: +125℃ Dwell time: 15min Number of cycles: 5,000	Visual	No open circuit, blistering, measling, crazing or delamination.	PASS
4			Change in connection resistance	Max. 0.36% (Requirements: less than 10%)	PASS
5			Insulation resistance	Min. 1E+10Ω (Requirements: more than 5E+8MΩ)	PASS
6			Dielectric withstanding voltage	No exhibit insulation breakdown, flashover or sparkover	PASS
7			Microsection	No defect	PASS
8	Humidity and Insulation Resistance	Min. temp: 25℃ Max. temp: 65℃ Humidity: 90 to 98% Number of cycles: 20 Applied voltage: 100V	Visual	No blistering, measling or delamination	PASS
9			Insulation resistance	Min. 6E+10Ω (Requirements: more than 5E+8MΩ)	PASS
10			Dielectric withstanding voltage	No exhibit insulation breakdown, flashover or sparkover	PASS
11	Interconnect Stress Test	Precondition: 230℃X3times Peak temp: 190℃ Number of cycles: 3,000	Change in connection resistance	Max. 1.4% (Requirements: less than 4%)	PASS

Reliability test result (microsection of after thermal stress)

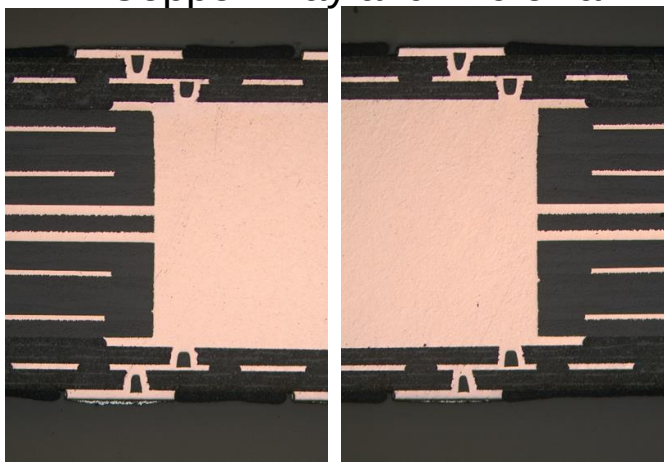


Microvia



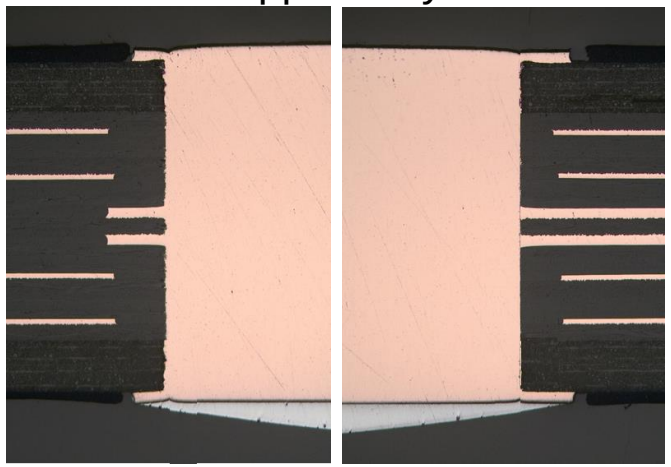
No separation interconnect of microvia pad

Copper inlay and Microvia



No laminate clacks of around the copper inlay and no separation and other defect of microvia

Copper inlay



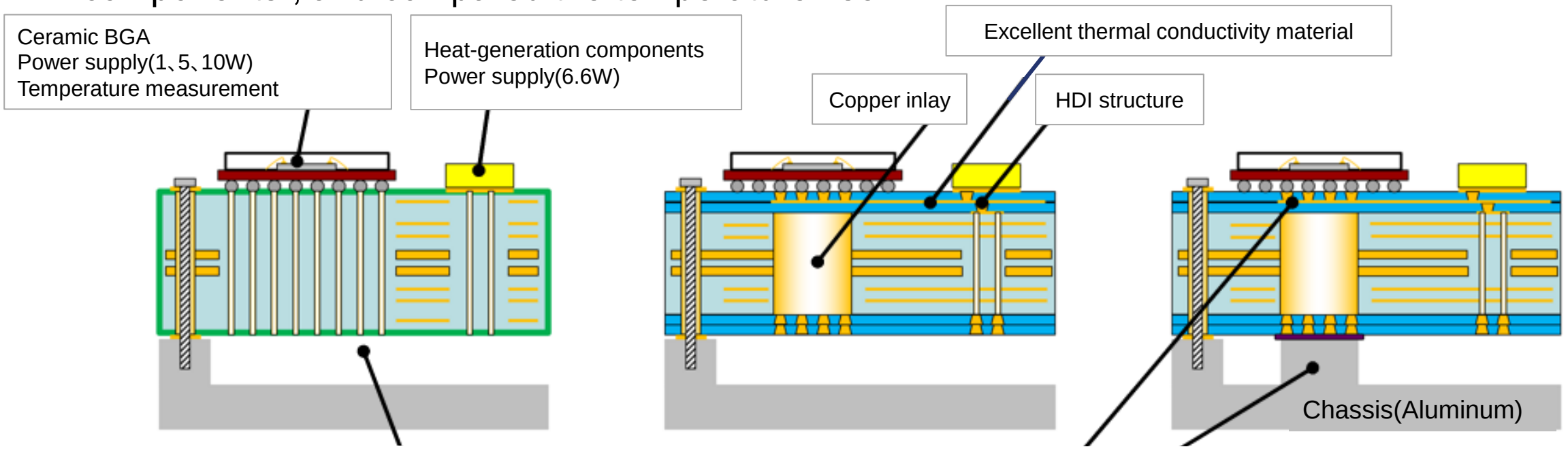
No laminate clacks and other defect of around the copper inlay

Contents

Souse from JAXA

Effectiveness of PCB structure (Comparison of thermal conduction)

We mounted the two components, “Ceramic BGA components” and “heat-generation components”, and compared the temperature rise.



General material

Directly below the Heat-generation components, PTH is located and there is electrical continuity, so it cannot be contact to the chassis.

Type 3:Excellent thermal conductivity material

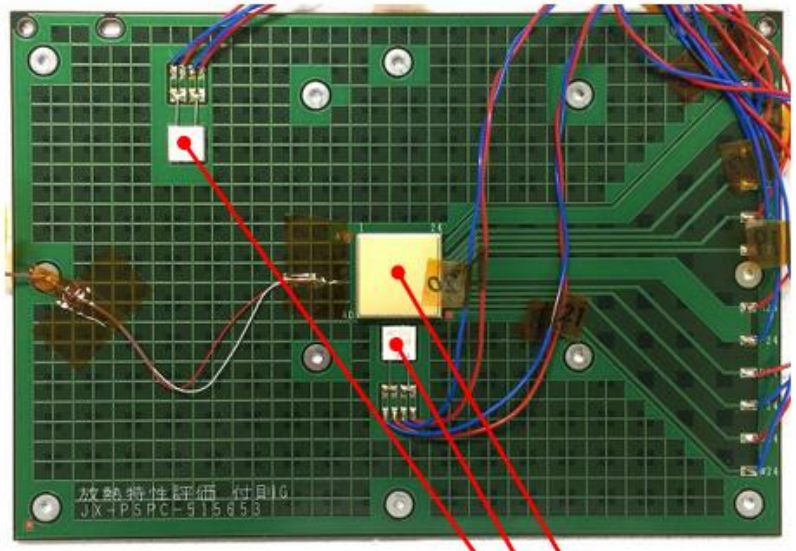
By adopting the HDI structure, it is possible to insulate any location, so it is possible to contact the chassis directly under the heat generating components.

Souse from JAXA

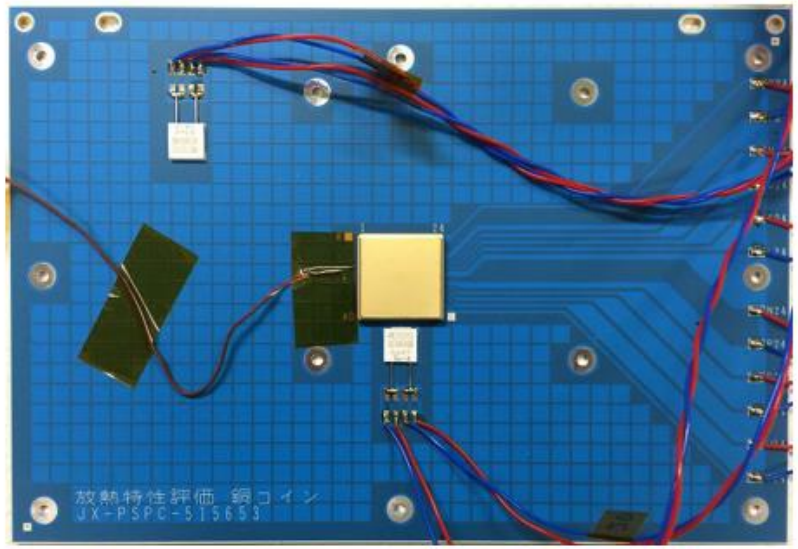
Effectiveness of PCB structure(Figure of evaluation sample)

Mounting components on PCBs with General material and type 3 structures and measuring changes in heat generation
*For the two heat-generating parts, the measurement was performed with 6.6W applied.

PCB
160x233.3mm



General material



Type 3:Excellent thermal conductivity material

Ceramic BGA
(26x26mm)

Heat-generation components(2 each)
Ceramic resistor(10x10mm)

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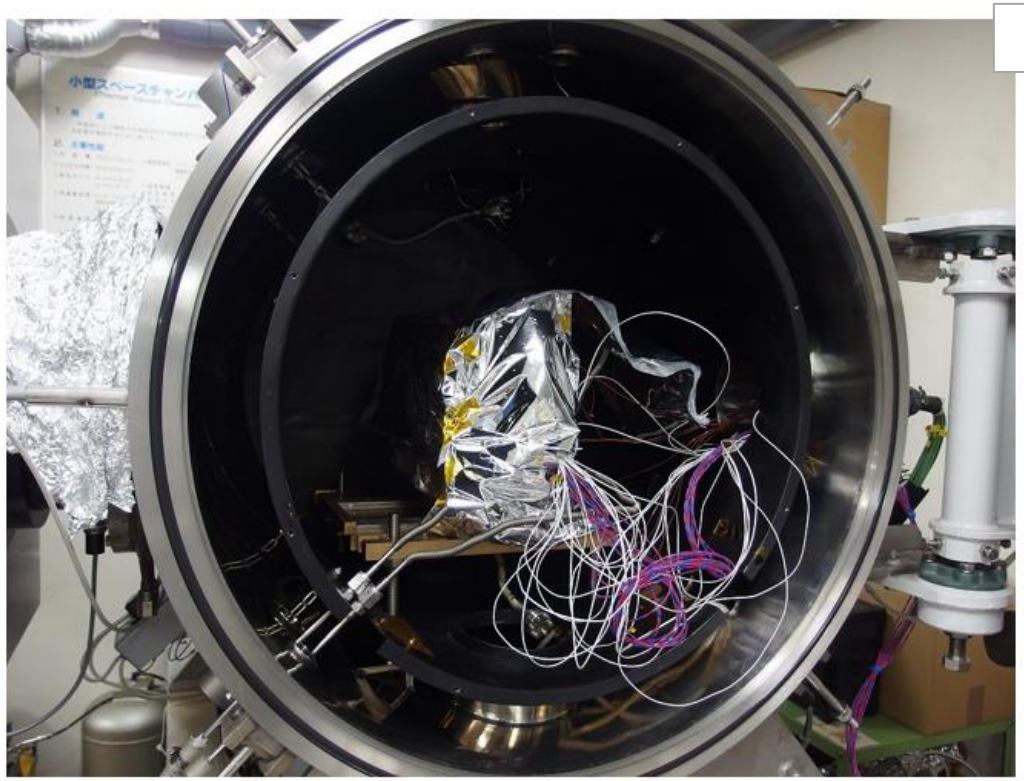
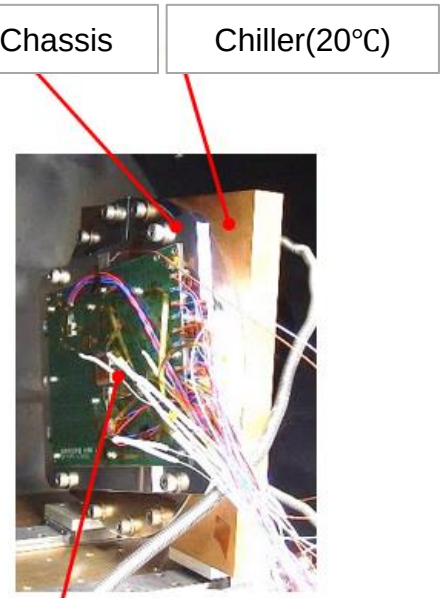
Effectiveness of PCB structure (Figures of under evaluation)

- Assuming outer space, evaluation was conducted in a vacuum chamber.



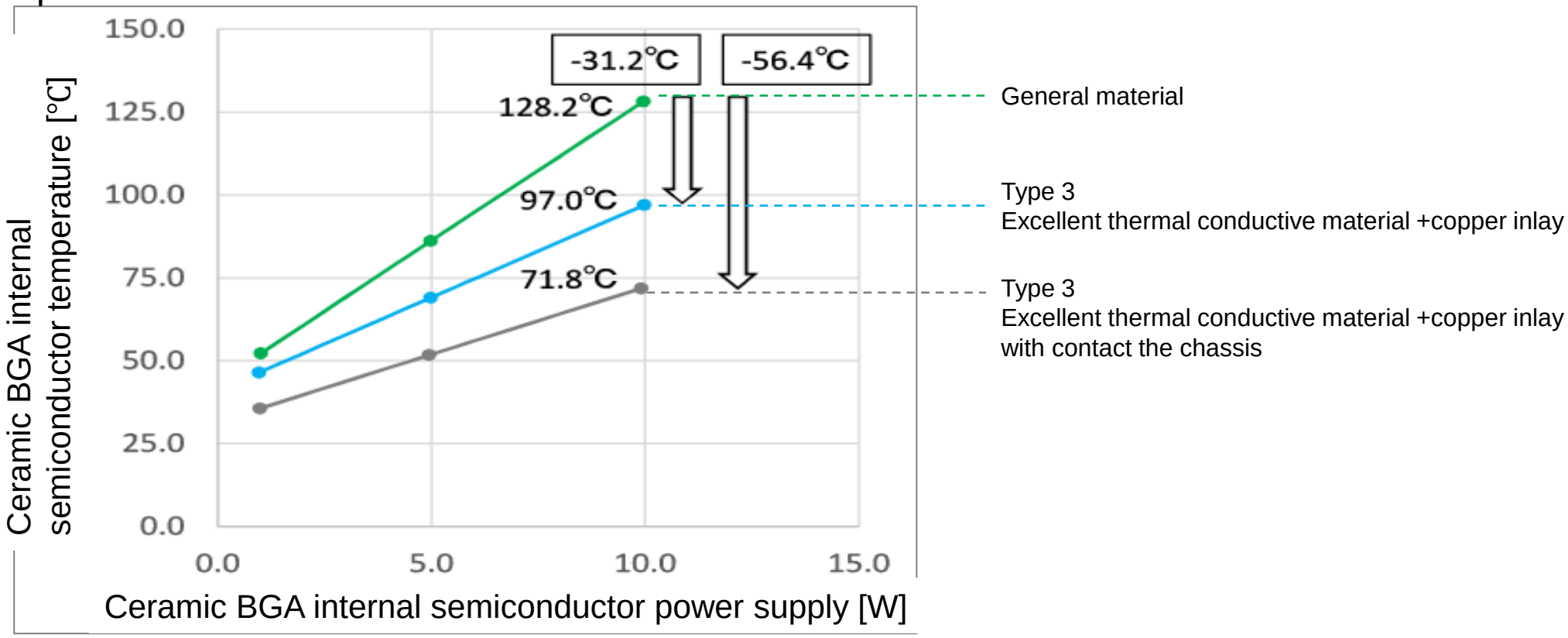
Arrangement in vacuum chamber



Souse from JAXA

Effectiveness of PCB structure(Result)

In the case of this sample, it was confirmed that the high thermal conductivity substrate (Type III), which has good thermal conductivity, the temperature dropped 30℃ or more at the time of semiconductor 10 W heat generation compared to the conventional substrate (General material).
As a result, the life of the component is extended, and the failure rate is expected to be reduced and reliability improved.



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Conclusion

- Confirmed that there is no any problem of reliability of evaluated high heat dissipation PCB
- Verified to be able to expect decreasing thermal more than 30 ℃ in case of 10W generation of heat of semiconductor in comparison with conventional normal PCB on high thermal conductivity PCB
- As that result, getting longer of component lifetime, decline of defective rate, improvement of reliability are expected

Future plan

- Promote to supply as JAXA certificated components by new structure
- Expand to apply to surface infrastructure equipment
- Proceed evaluation of applied products that enhance heat dissipation effect(convex shape copper inlay)

Thanks

We would like to express much appreciation to JAXA for their support and cooperation.

Open up your dreams

We will continue to develop and supply state-of-the-art printed circuit boards for the safety, security, and dreams of humanity