MEWS 23

Thermal characteristics analysis for reliability improvement of electronic equipment

November 11, 2010

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Reliability Department
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Introduction ～ Necessity of thermal characteristics analysis ～

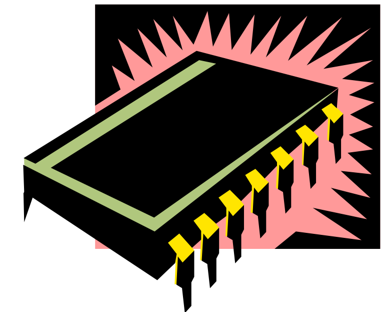
The amount of the heat of the device is growing,
like high-brightness LED ,high-performance LSI and high-power device, etc.

However…
Enough heat radiation measures might not be taken by some limitations.

In general, in the semiconductor device case…
Rise of junction temperature
→ life-time degradation & increasing of failure rate (Reliability degradation)
※Si semiconductor ; It breaks when Tj exceeds about 150°C.

What is countermeasure?

It is necessary to consider & design enough heat radiation at the design stage of the systems or devices.



Thermal resistance that is one of the important heat characteristic parameters for thermal design, should be measured with high accuracy and easily.

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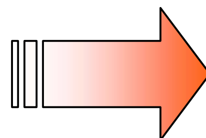
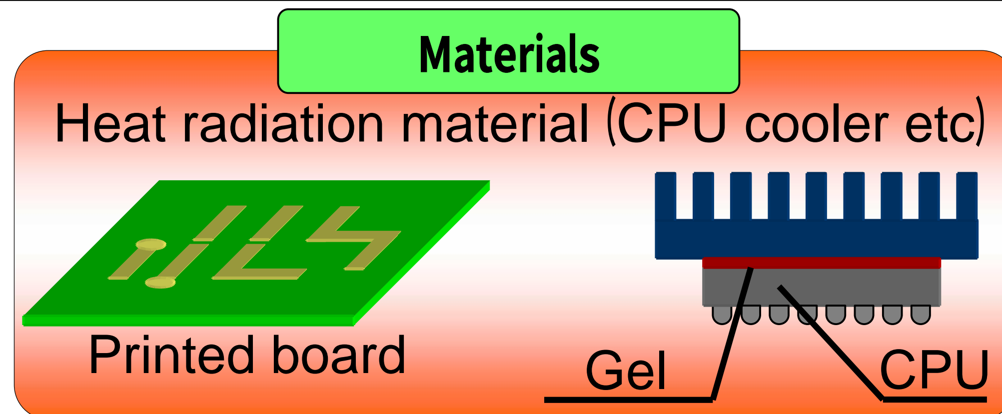
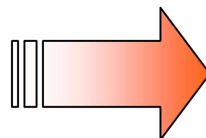
Introduction 〜 Conventional evaluation method 〜

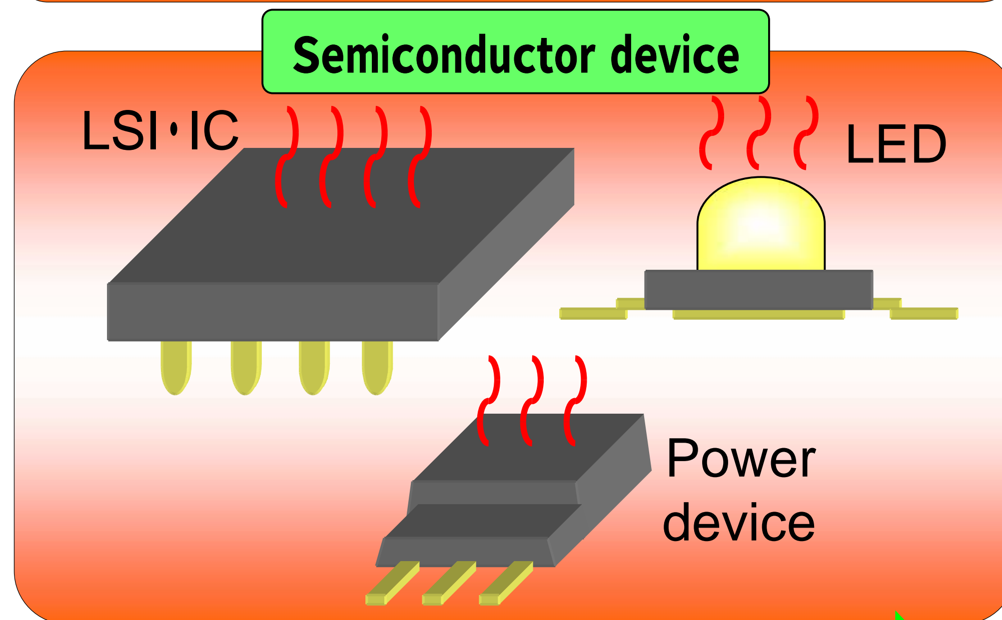
●Method
using thermo-couple





●Method using TEG
●Method using actual device





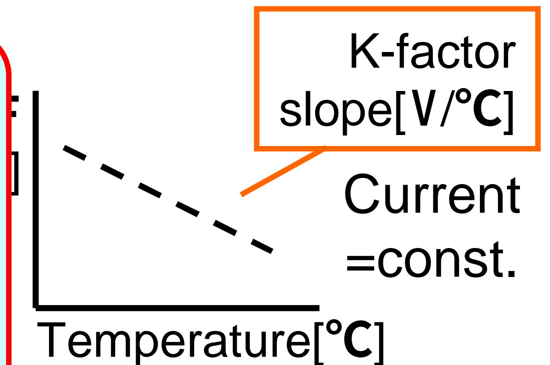
●Decline of measurement precisio
●Can not obtain the structure info

New evaluation approach
『Thermal transient characteristics analysis』

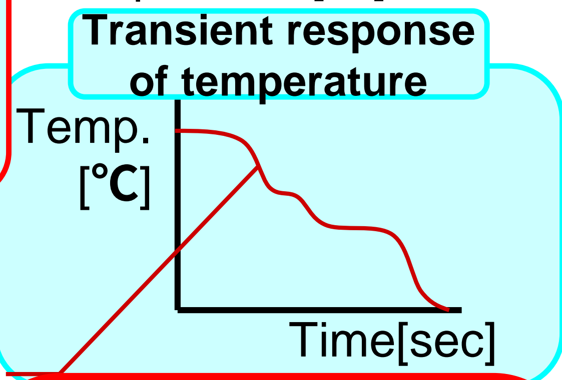
Introduction ～ measurement flow ～

【Peculiarity of thermal transient characteristic analysis】
～Improvement from conventional method～

●The definition of a detailed structure not obtained by a conventional method is realized according to the fast measurement as every μ seconds class.
●Conversion from the transient response characteristics of the temperature to *the structure function* is enabled to be calculated easily by a special application.



A transitional VF change during cooling is monitored every μ seconds
VF is converted to the temperature by using K-factor.

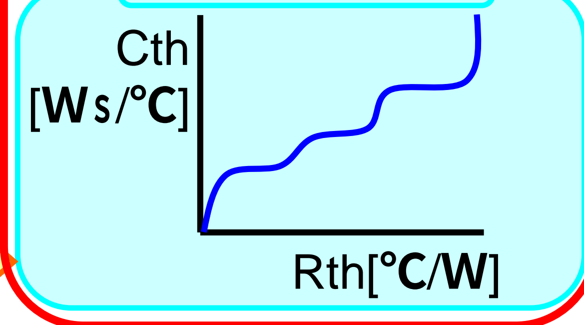


As the heat transmission is peculiar to each structure material, the structure information on the package is able to obtain from the temperature change of the diode.

convert

●Thermal transient characteristics analysis

・Conversion to the structure function



The thermal resistance & capacitance of each composition material is obtained from *the structure function*.

comprehension of structure function

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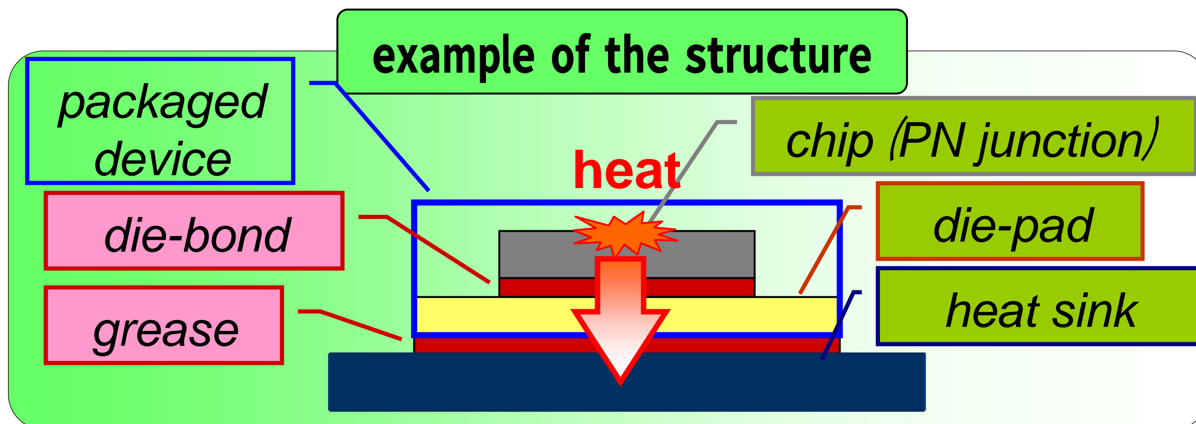
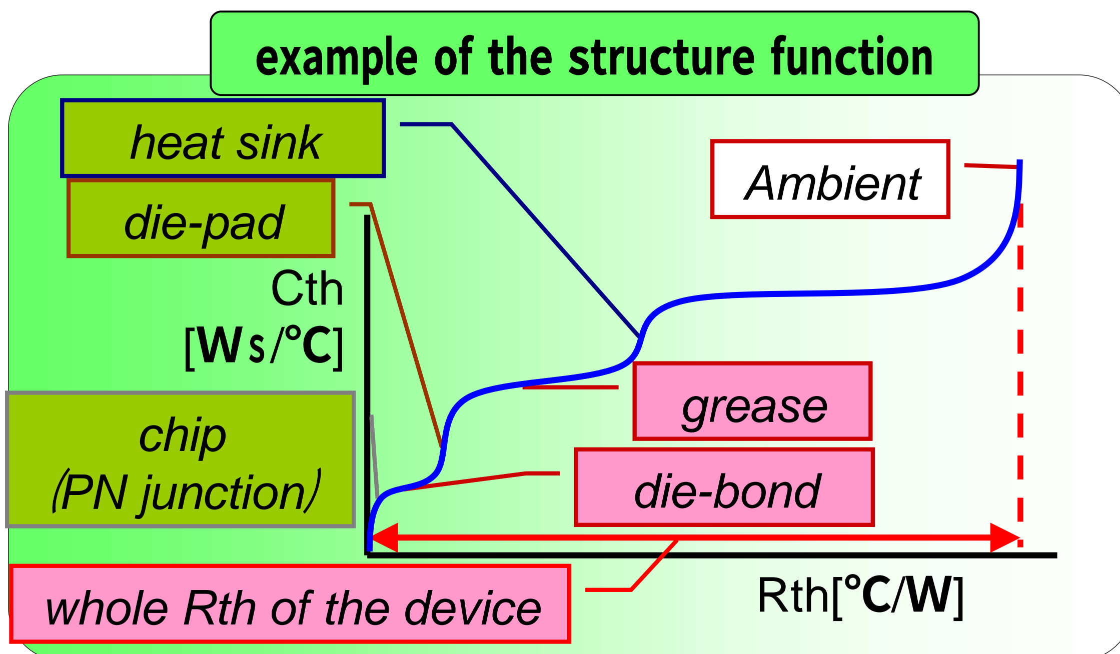
Introduction 〜 Structure function 〜

●Image of the structure function





Thermal conductivity
→ Shown by the inclination

●Low thermal conductivity
＝High thermal resistance
⇒ **Small inclination**
(die-bond, grease, etc…)

●High thermal conductivity
＝Low thermal resistance
⇒ **Large inclination**
(Metal, Si-chip, etc…)

Thermal resistance & capacitance in each structure part can be evaluated by the thermal transient characteristic analysis.

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Introduction ～ Evaluation example ～

●Evaluation example of the LED light

・Purpose

Applied the “Thermal transient characteristics analysis" to the LED light.

→ Comparing the structure function. → Consider about a thermal quality.

・Samples

LED light×4 kinds (company A, B, C, D ; close power type)

・Measurement condition

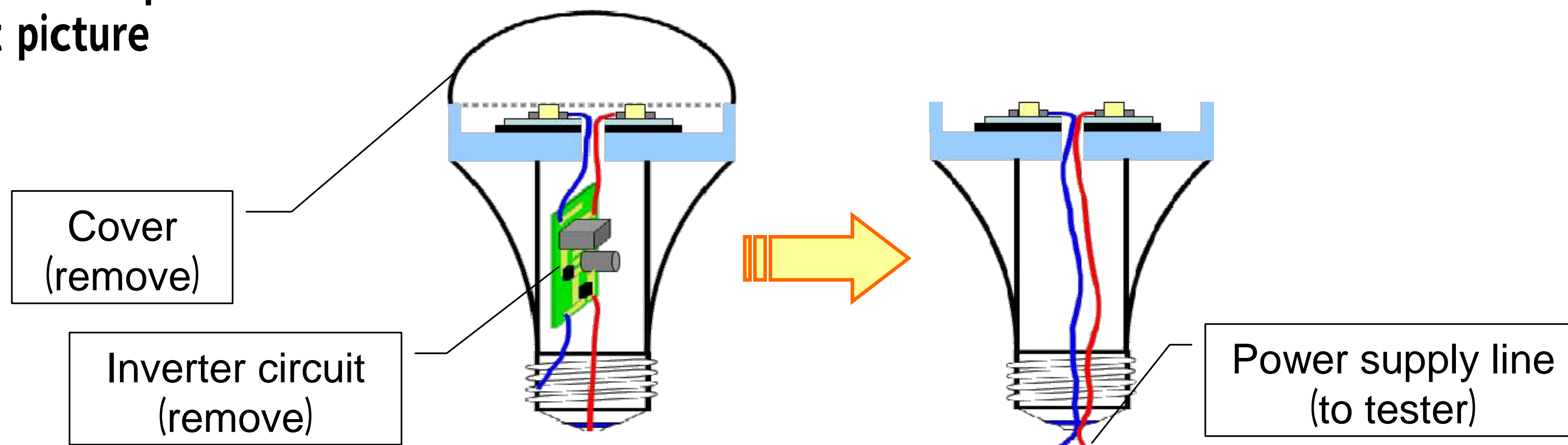
Heating current；DC current that flows to the LED-terminal when AC100V operates.

Heating time, Measurement time；Heat saturated condition

Sensing current；Small self-heat condition (＜1℃)

・State of sample

Right picture



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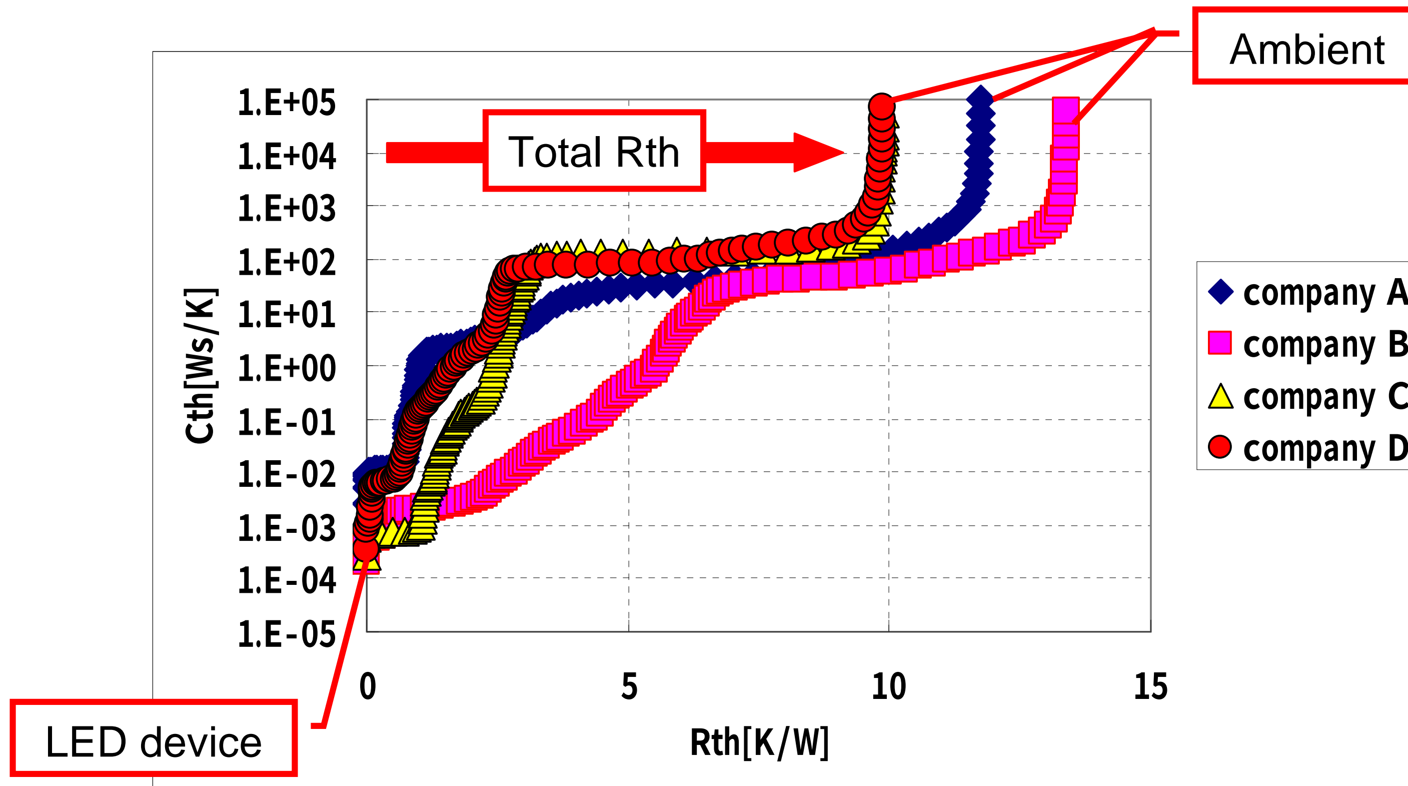
Introduction 〜 Evaluation example 〜

●Evaluation example of the LED light ; Evaluation results (structure function)



	company A	company B	company C	company D
Total Rth [K/W]	11.75	13.39	9.92	9.88

Fin-less structure

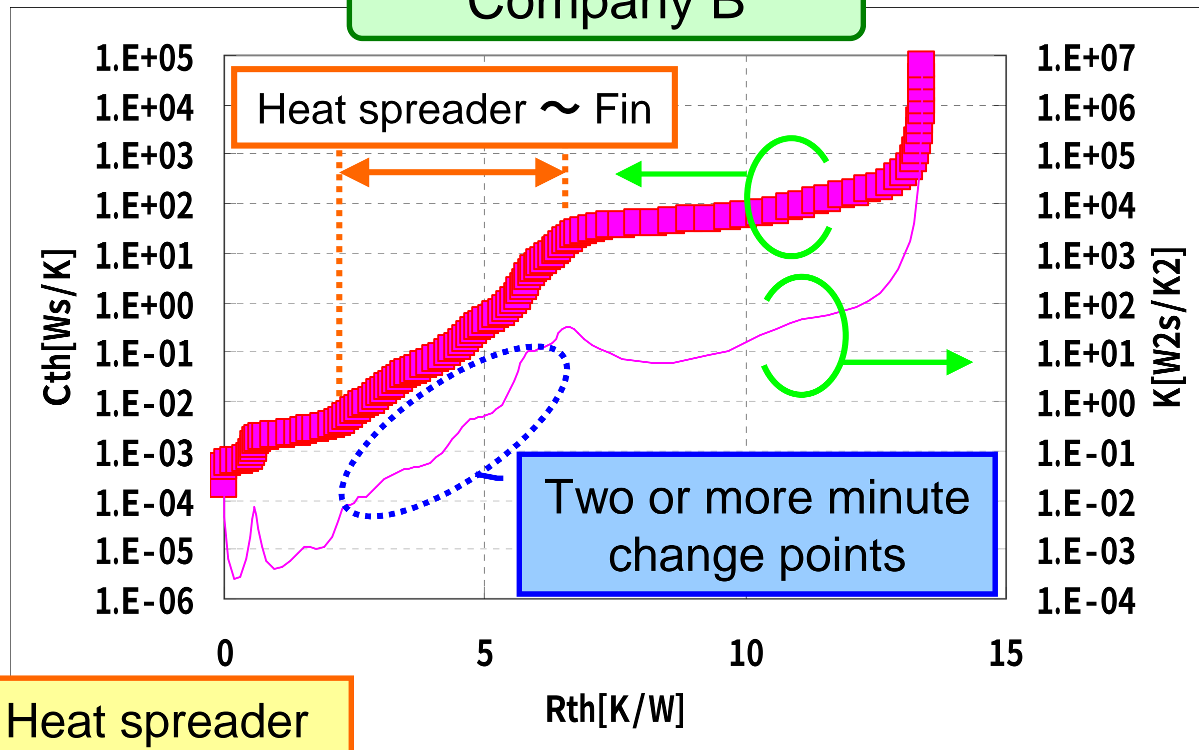
Light-weight fin

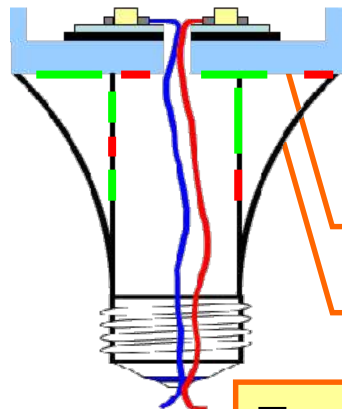
The difference in total Rth is caused by the fin structure.

Why the Rth of B company product was high?

Introduction 〜 Evaluation example 〜

●Evaluation example of the LED light ; Evaluation results & consideration (differentiated structure function)





Two or more minute change points are seen between the heat spreader and the fin.
→ Good connection parts and incomplete connection parts exist in parallel.
→ The decrease of thermal resistance is expected by improving the connection.

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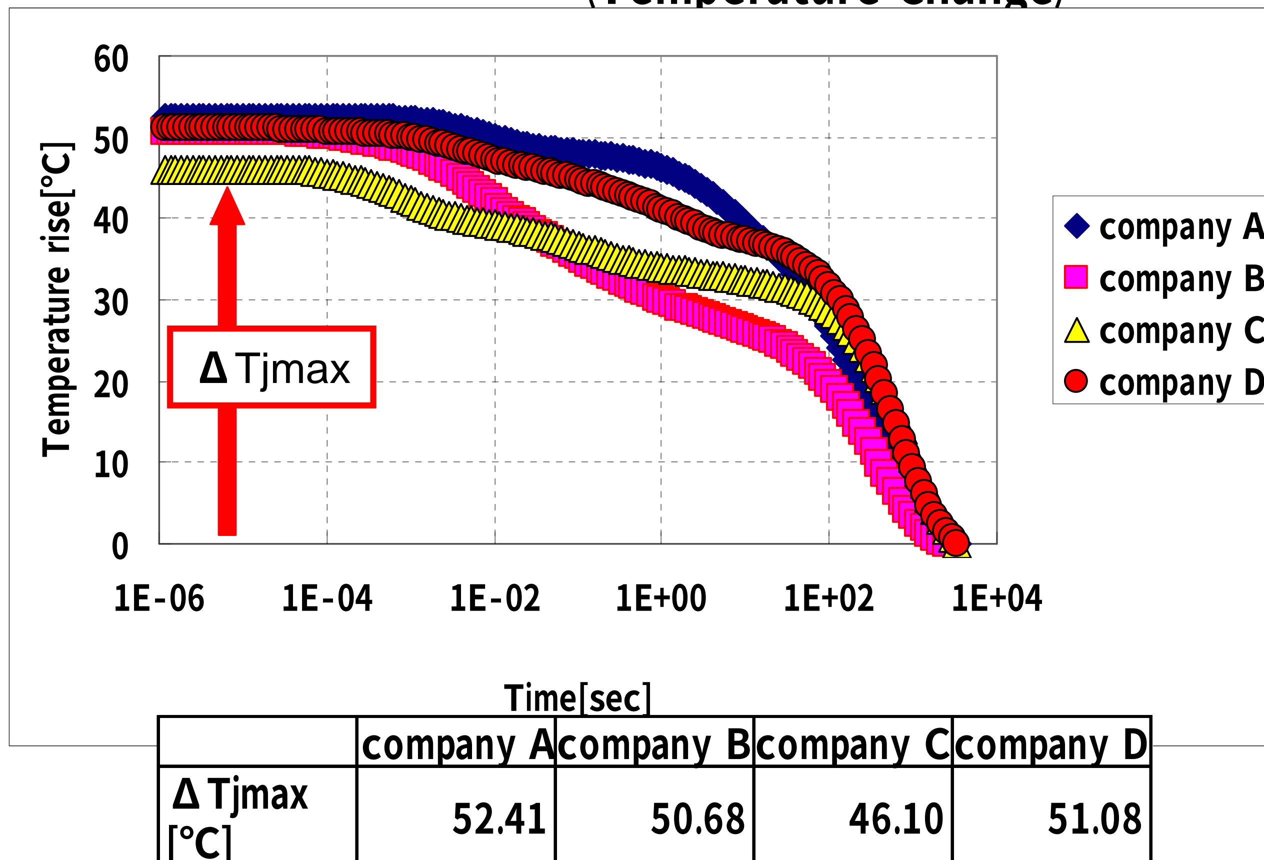
Introduction ～ Evaluation example ～

●Evaluation example of the LED light ; Evaluation results & consideration (Temperature change)



	company A	company B	company C	company D
ΔTjmax [°C]	52.41	50.68	46.10	51.08

The junction temperature is about 80**°C** in all products. (R.T. 30**°C**)
→ The problem on thermal reliability may be not so high.
The rise of the junction temperature of C company product is especially small.
→ Advantage in the thermal design (power and Rth).

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Introduction 〜 Evaluation example 〜

●Evaluation example of the LED light ; Conclusion

・Purpose
Applied the "Thermal transient characteristics analysis" to the LED light.
→ Comparing the structure functions. → Consider about a thermal quality.

●Total Rth of A and B company product is higher than that of C and D.
→ It is caused by the fin structure.

●B company product contain the incomplete fin-connection, and it causes high thermal resistance.
→ The decrease in thermal resistance is expected by improving the connection.

●The actual junction temperature of all samples are around 80C, and there is not so high impact to the thermal reliability.（There are some advantages in C company product.）

Measuring the total Rth
→ Verification of catalog specs data

Extracting the thermal resistance of each material from the structure function
→Specifying the part with the problem in thermal design. →Considering the countermeasure.

Acquiring the temperature of the P-N junction.
→ Considering the influence on reliability from the P-N junction temperature.

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Thermal transient characteristics analysis under decompression condition

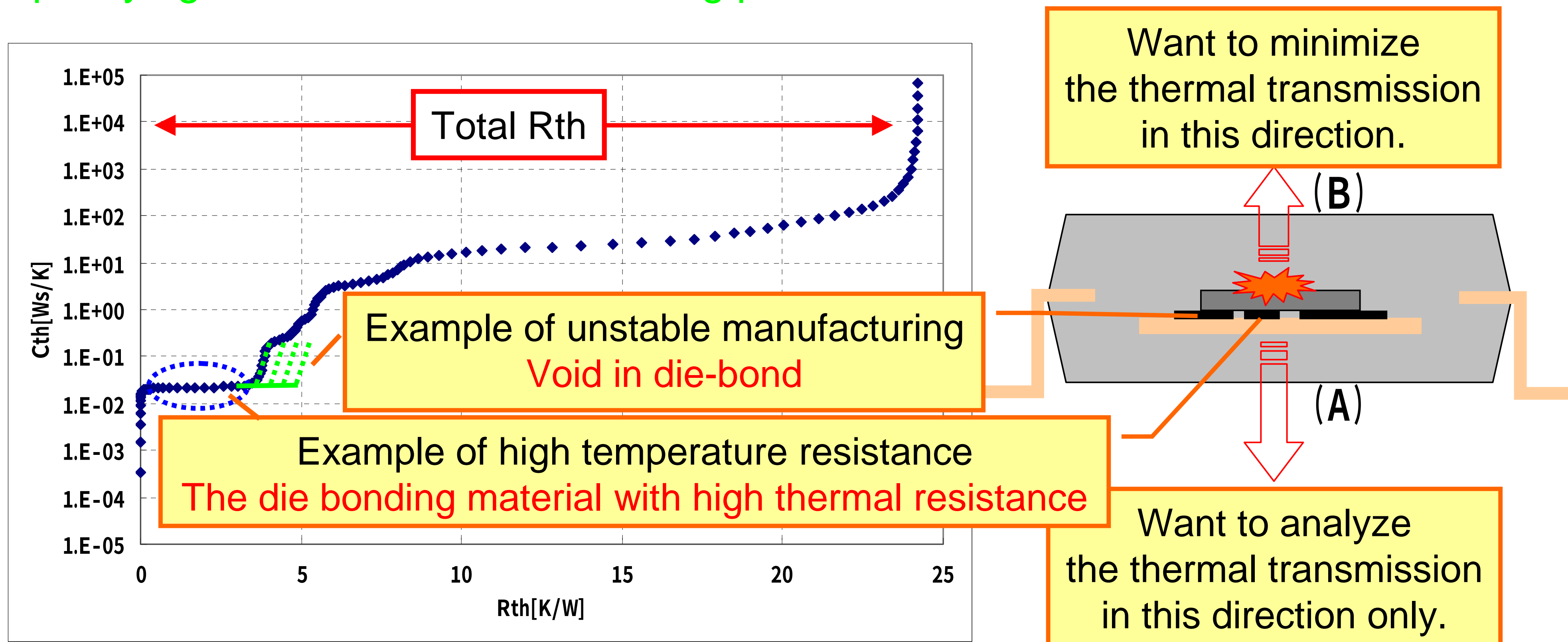
～ Purpose ～

●Example of evaluation items by thermal transient characteristic analysis

・Obtaining the total thermal resistance(Total Rth) of the semiconductor device.

・Specifying the high thermal resistance part in the device.

・Specifying the unstable manufacturing part.



In a usual measurement, the characteristic A and B are superimposed.
→ What is countermeasure?

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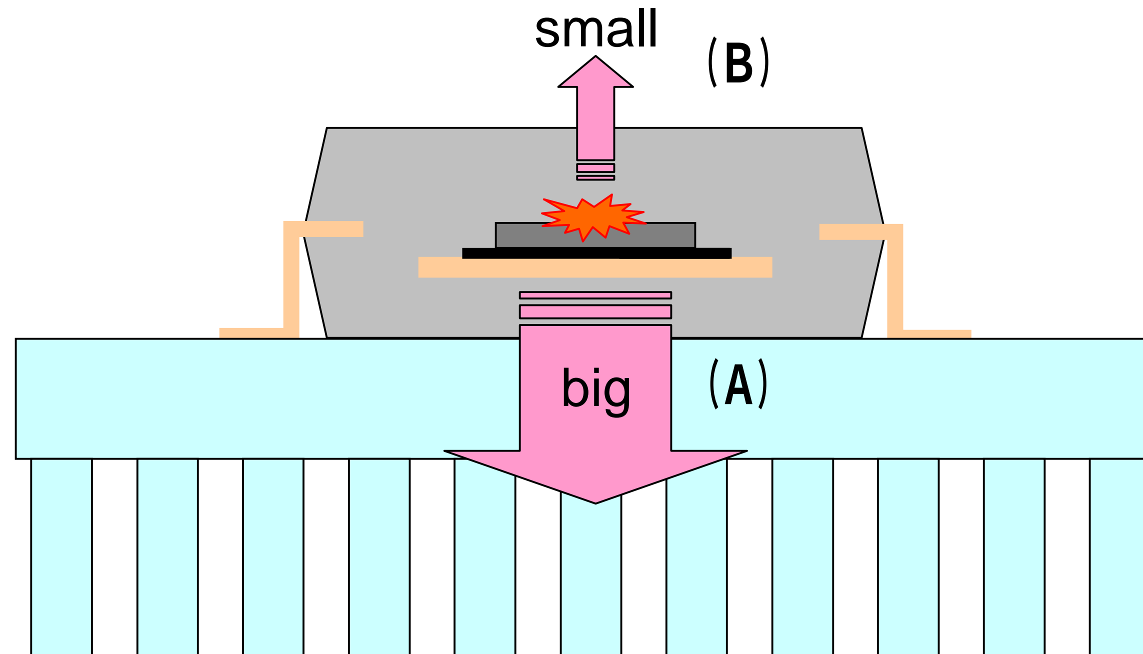
Thermal transient characteristics analysis under decompression condition

～ Purpose ～

●Using heat sink → The direction of heat transmission can be limited.



However, even if use a heat sink,
●The heat transmitted to B direction is remain.
●The large thermal capacity heat sink for reducing the element of B side cause the shortage of rising temperature of the device.
(The enough S/N ratio is not obtained)

Difficult to transmit the heat to B side.
→ Corresponding by losing the heat radiation medium (air).

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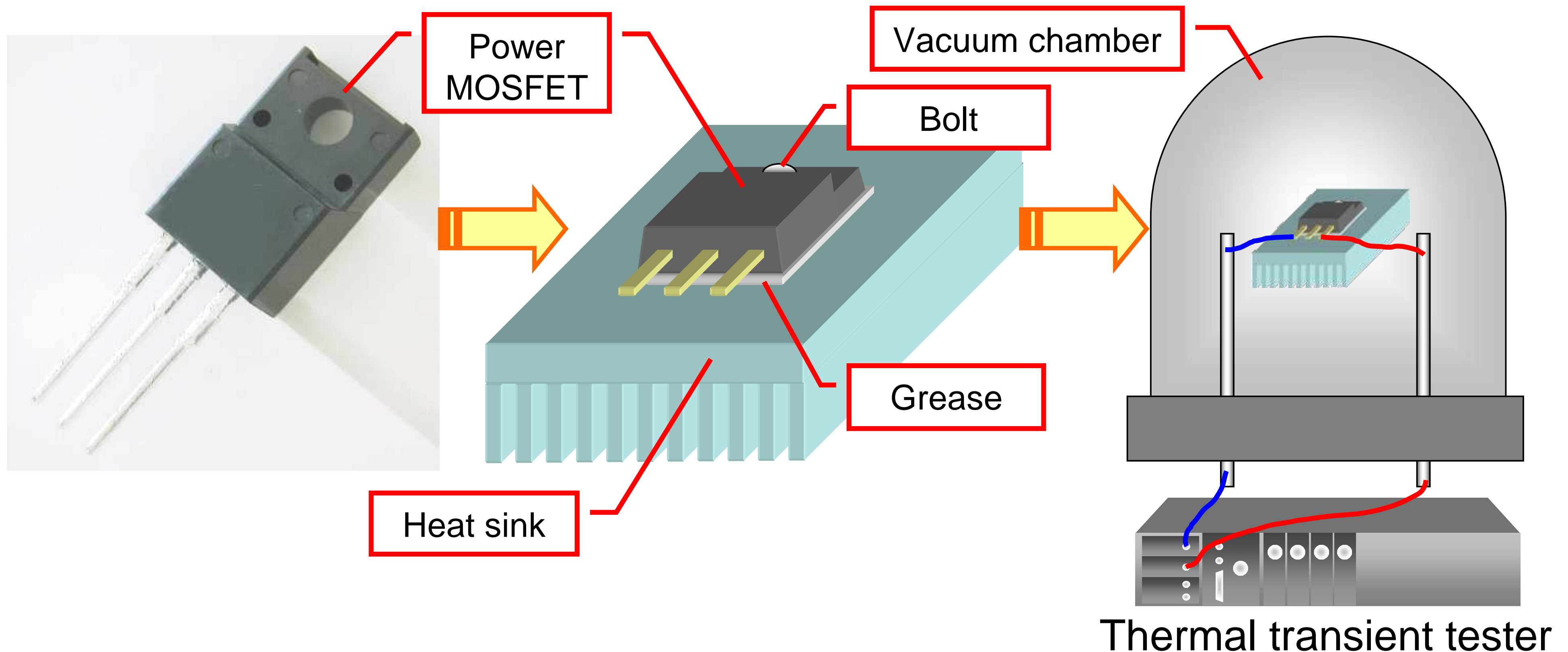
Thermal transient characteristics analysis under decompression condition

～ Evaluation method ～

- ●Device under test；Power MOSFET (TO-220 type package)
- ●State of device；Connected to the heat-sink with the thermal conductivity grease and fixed with bolt.
- ●Evaluative environment；DUT is set up in the vacuum chamber, and the thermal transient characteristic analysis is executed under the decompression condition.
- ●Decompression condition；about Air pressure (10^{+3})、10^{-1}、10^{-3}、10^{-5} [Torr]



Thermal transient tester

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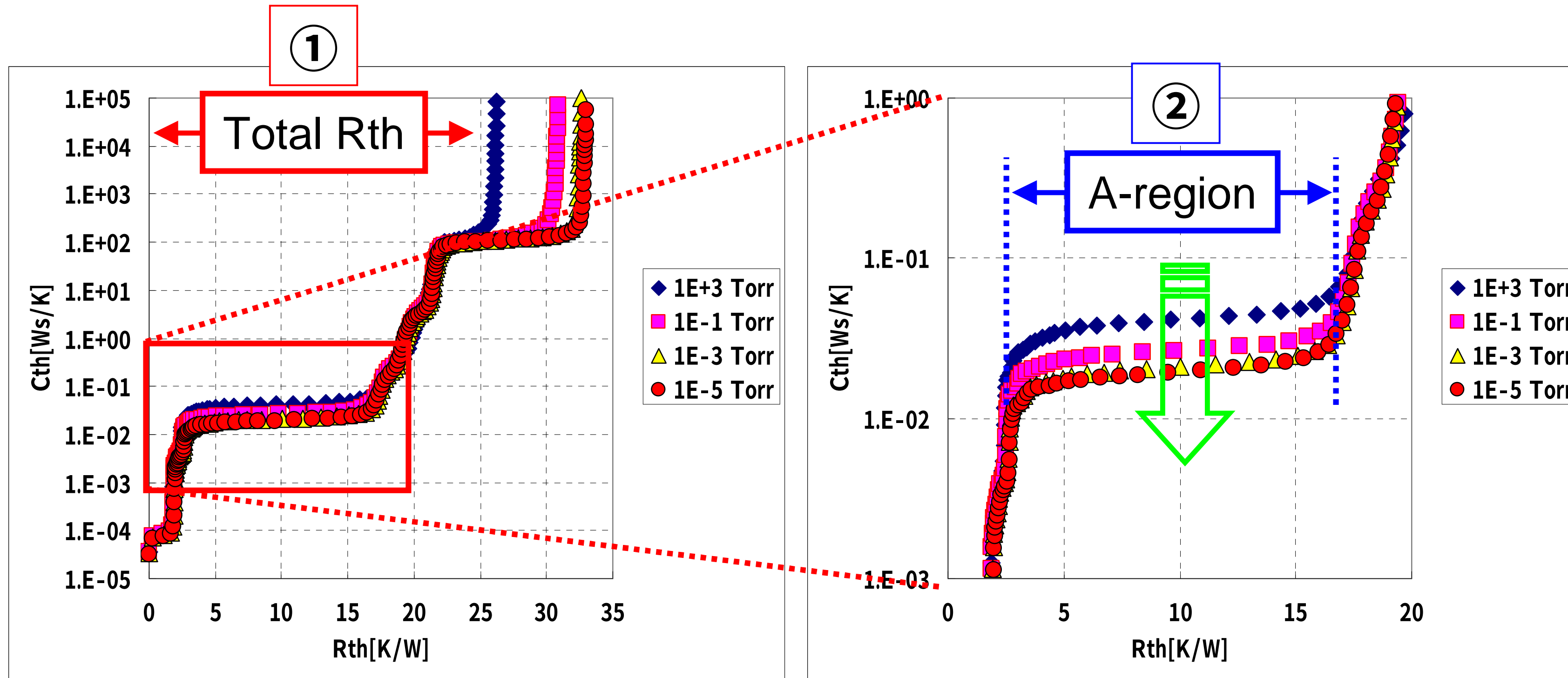
Thermal transient characteristics analysis under decompression condition ～ Results (Structure function) ～

●Results (Structure function)



The change on the structure function by decompression was chiefly the following two points.
①Increasing tendency of Total Rth
②Decreasing the thermal capacity in A-region.

Consideration about ①,②

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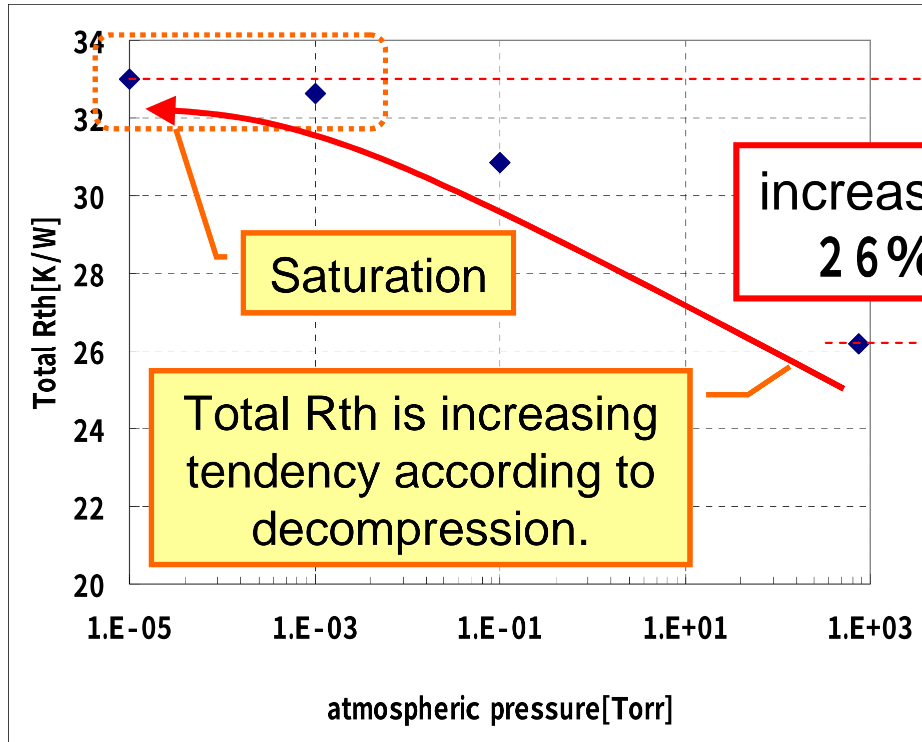
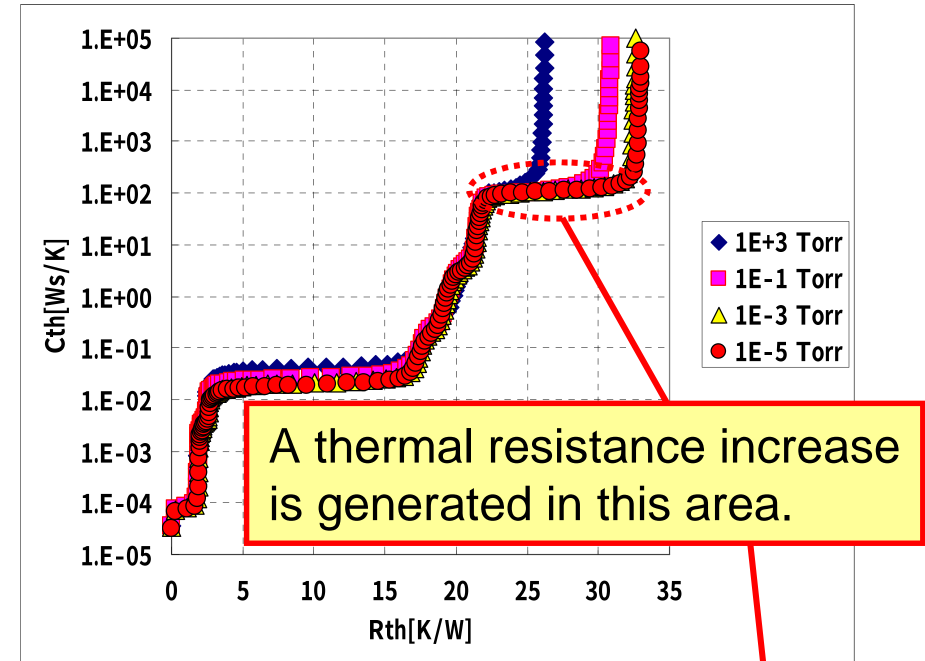
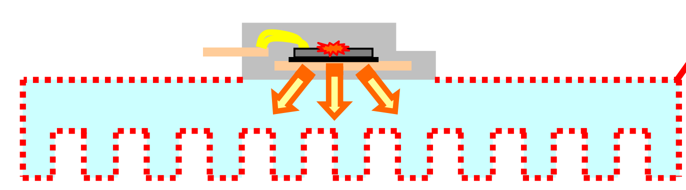
Thermal transient characteristics analysis under decompression condition ～ consideration ① ～

●Increasing tendency of total Rth



	1E+3 Torr	1E-1 Torr	1E-3 Torr	1E-5 Torr
Total Rth [K/W]	26.19	30.86	32.61	32.99





『Decompression (A decrease of heat transmitter around sample) → Total thermal resistance increases because the heat transmission from the sample outside edge to the ambient environment is limited.』

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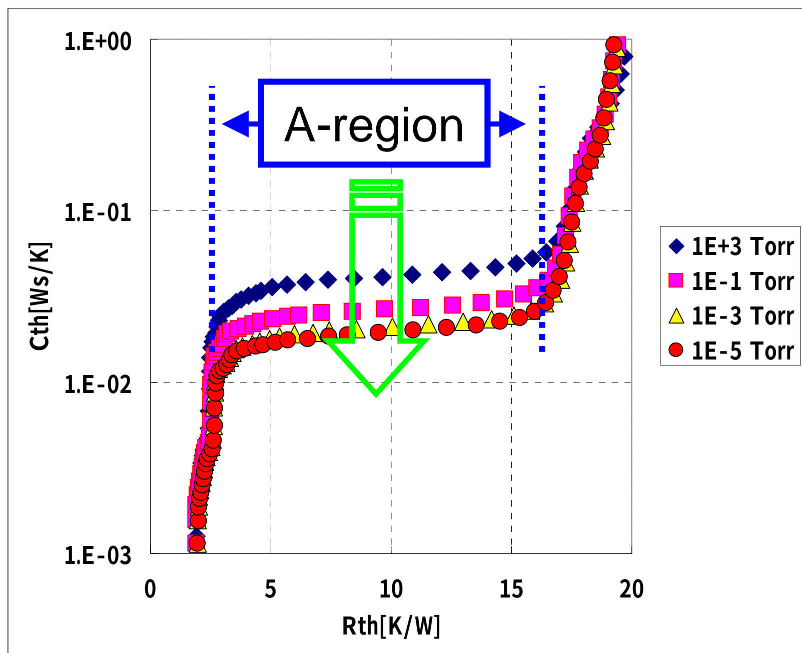
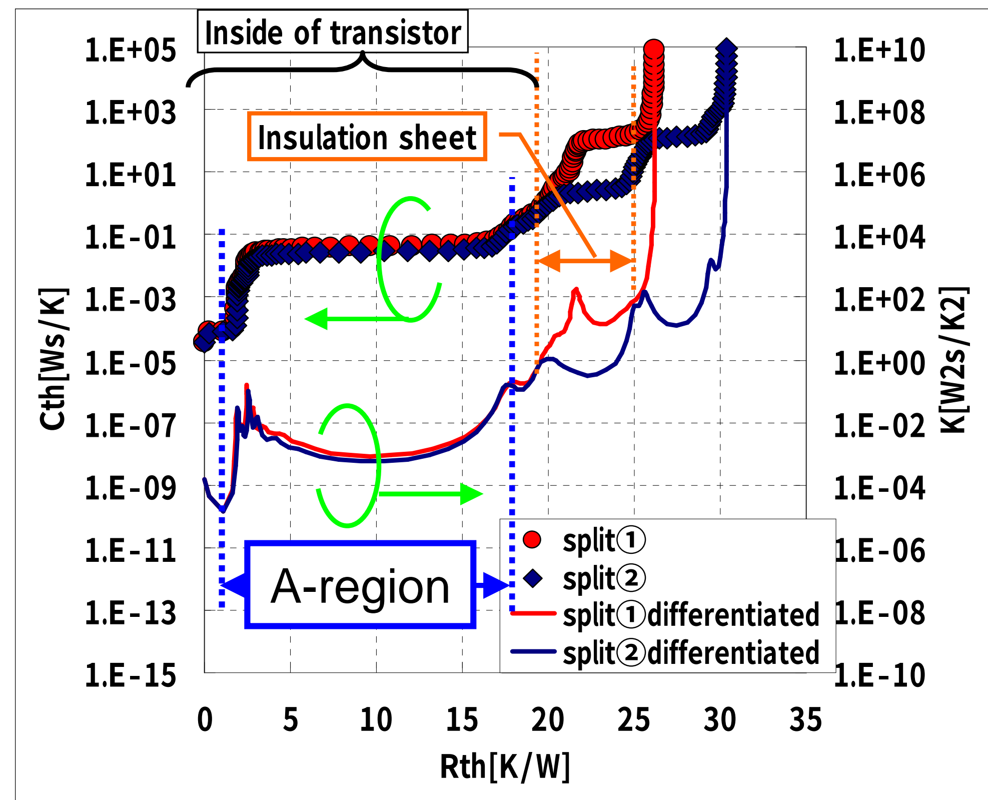
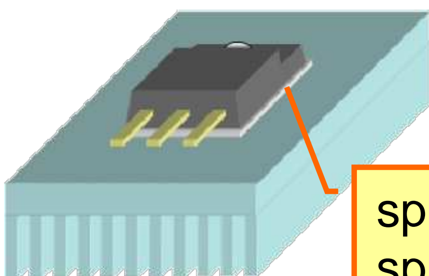
Thermal transient characteristics analysis under decompression condition ～ consideration ② ～

●Decreasing the thermal capacity in A-region.





Which structural part is A-region?
Splits evaluation → Specifying of structure



split ①Grease
split ②Insulation sheet

A-region is ･･･

●existing at the outside of device comparatively
●large Thermal resistance.
→ **Molding resin area in transistor device outer**

Explain more.

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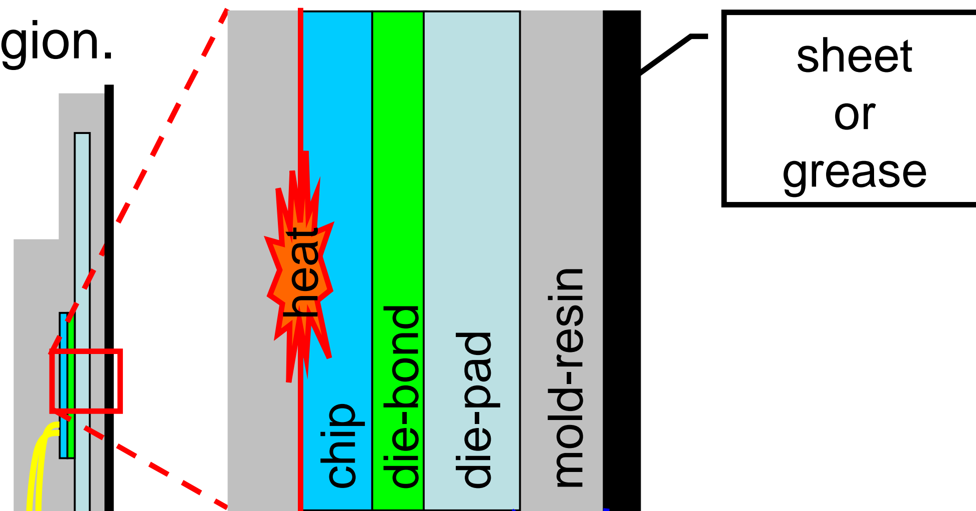
Thermal transient characteristics analysis under decompression condition ～ consideration ② ～

●Decreasing the thermal capacity in A-region.

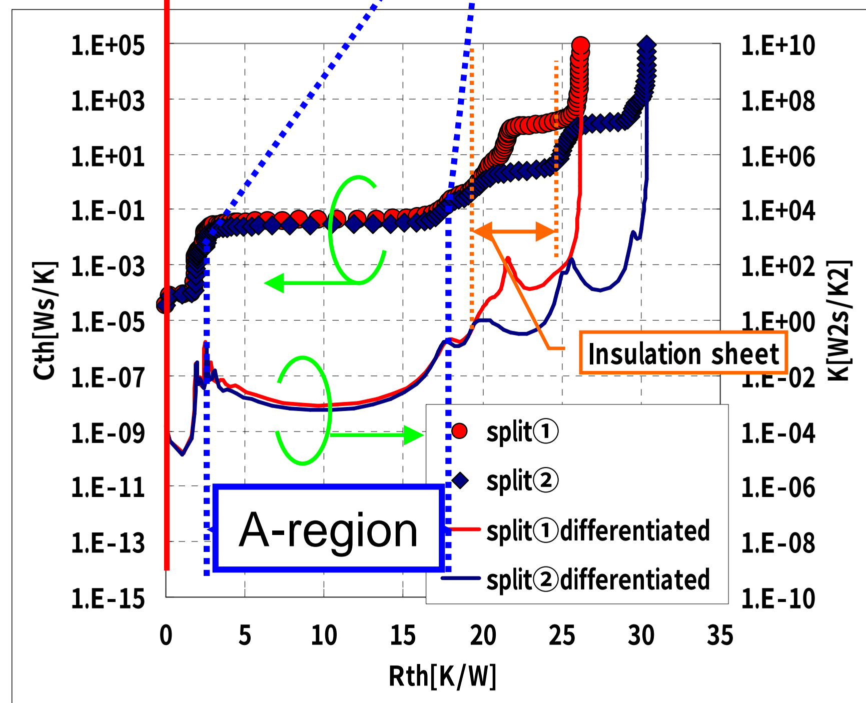


A-region is ･･･

●existing at the outside of device comparatively

●large Thermal resistance.

→ **Molding resin area in transistor device outer**



【why？】
The thermal capacity of the molding resin decreasing by decompression！？

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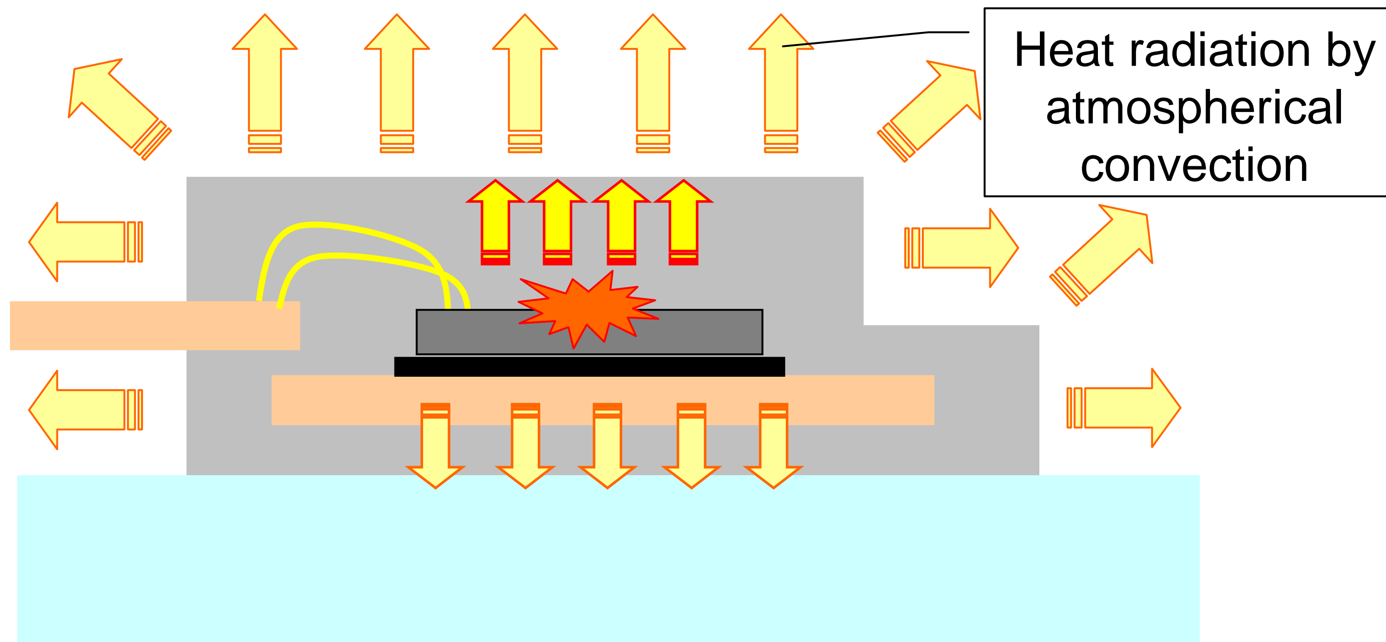
Thermal transient characteristics analysis under decompression condition ～ consideration ② ～

●Decreasing in thermal capacity in A-region



Heat radiation by the atmospherical convection is not generated under the decompression condition.
→ Heat radiation from the surface of the molding resin is not generated.
→ The heat that radiated to the atmosphere by convection under the normal pressure condition transmits to the heat sink side under the decompression condition.
→ Most heat transmits to the direction of the heat sink, and the heat transmission to the transistor surface side decreases.
→ The contributing rate to thermal capacity of the molding resin decreases.
→ It appears to the structure function as a decreasing in thermal capacity.

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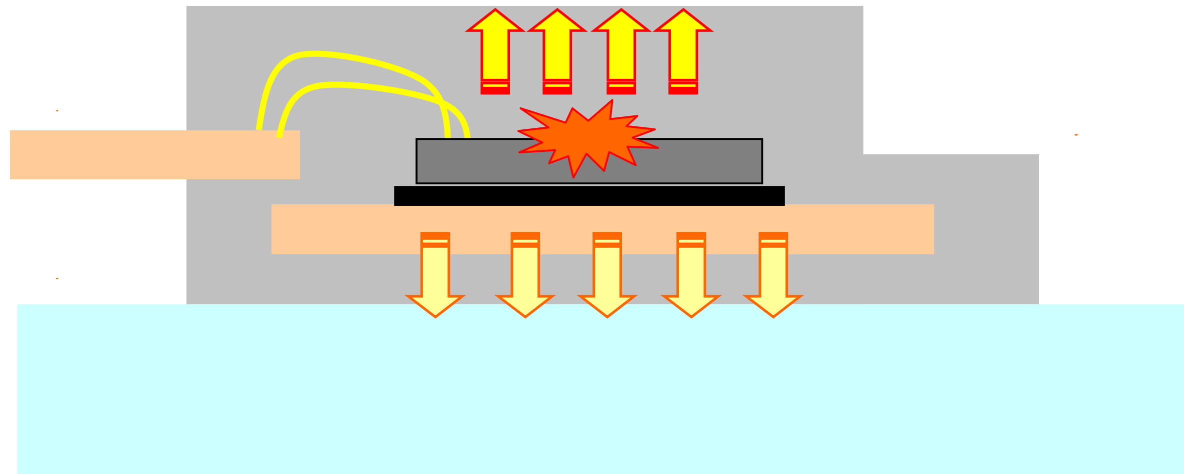
Thermal transient characteristics analysis under decompression condition ～ consideration ② ～

●Decreasing in thermal capacity in A-region



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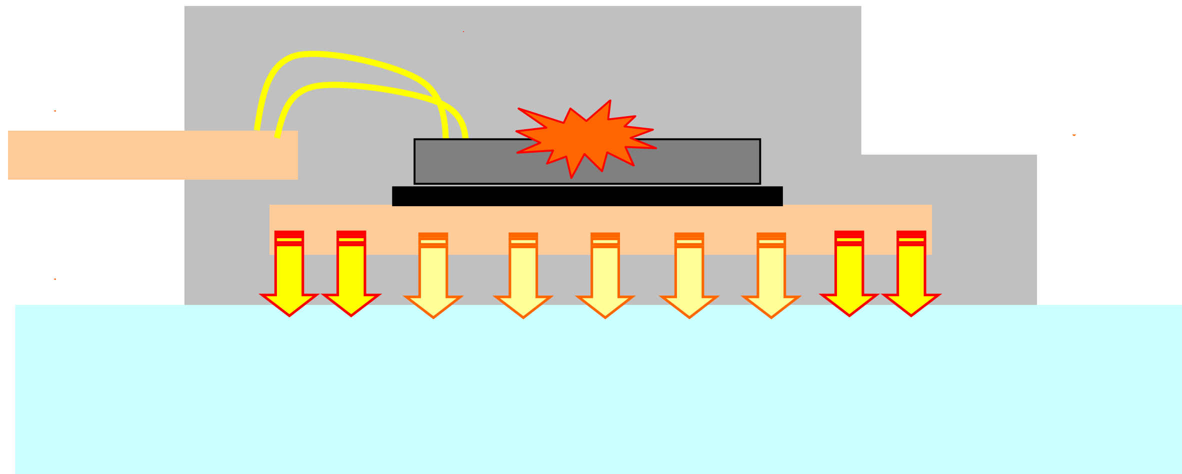
Thermal transient characteristics analysis under decompression condition
～ consideration ② ～

●Decreasing in thermal capacity in A-region



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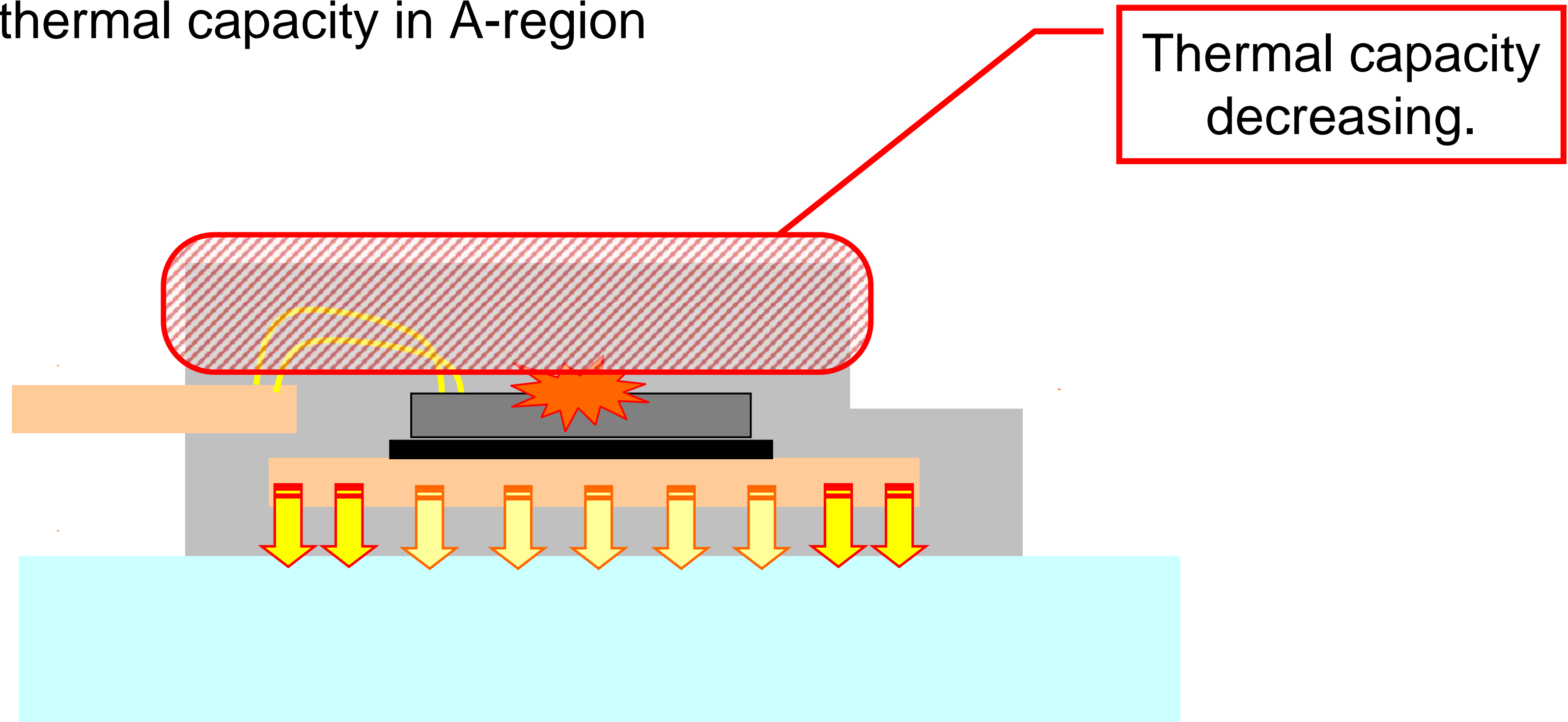
Thermal transient characteristics analysis under decompression condition ～ consideration ② ～

●Decreasing in thermal capacity in A-region



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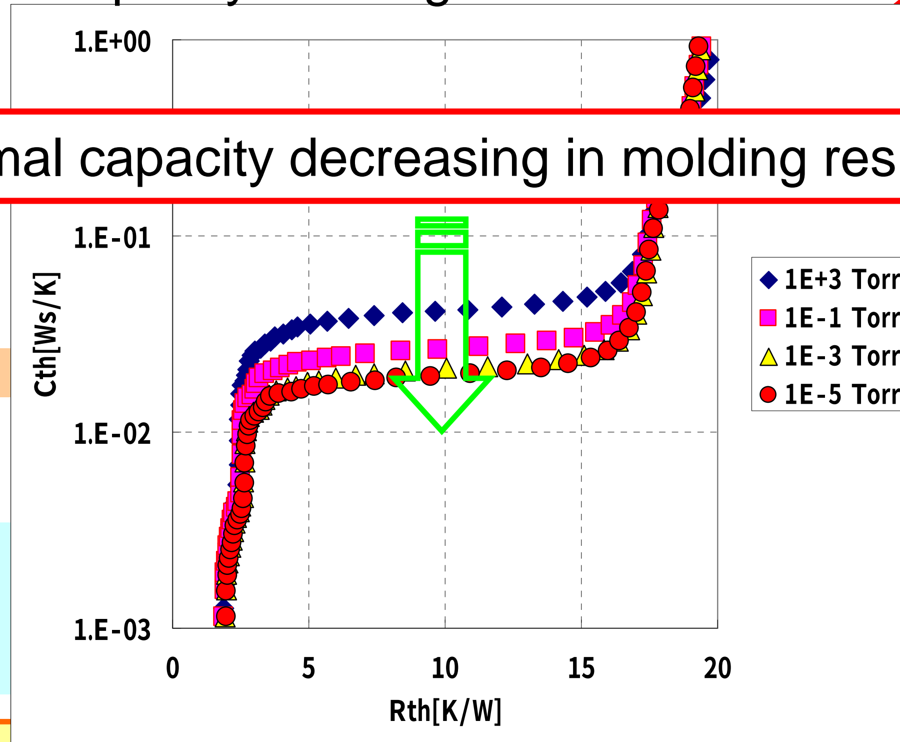
Thermal transient characteristics analysis under decompression condition ～ consideration ② ～

●Decreasing in thermal capacity in A-region

Thermal capacity decreasing.

A thermal capacity decreasing in molding resin part



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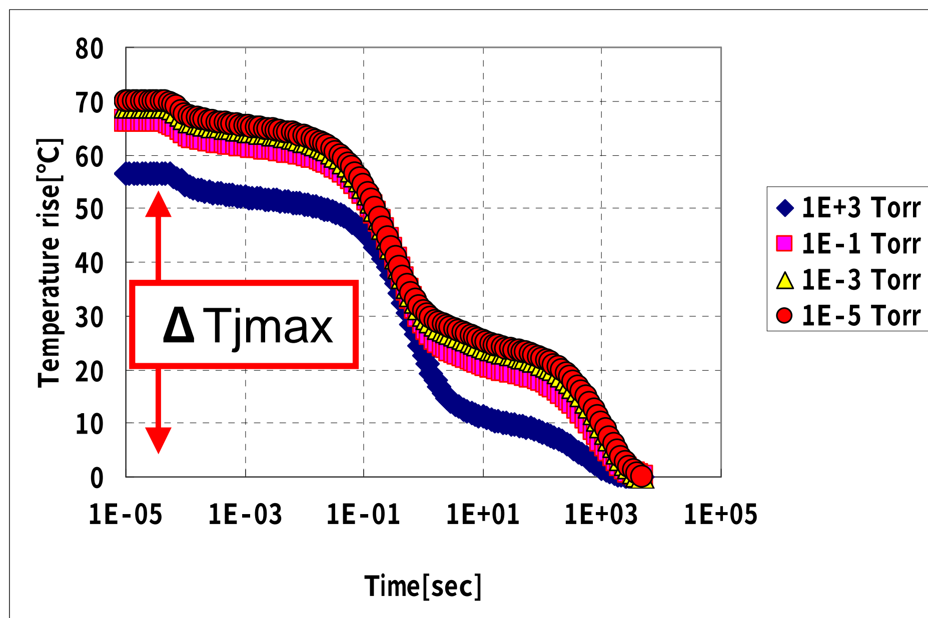
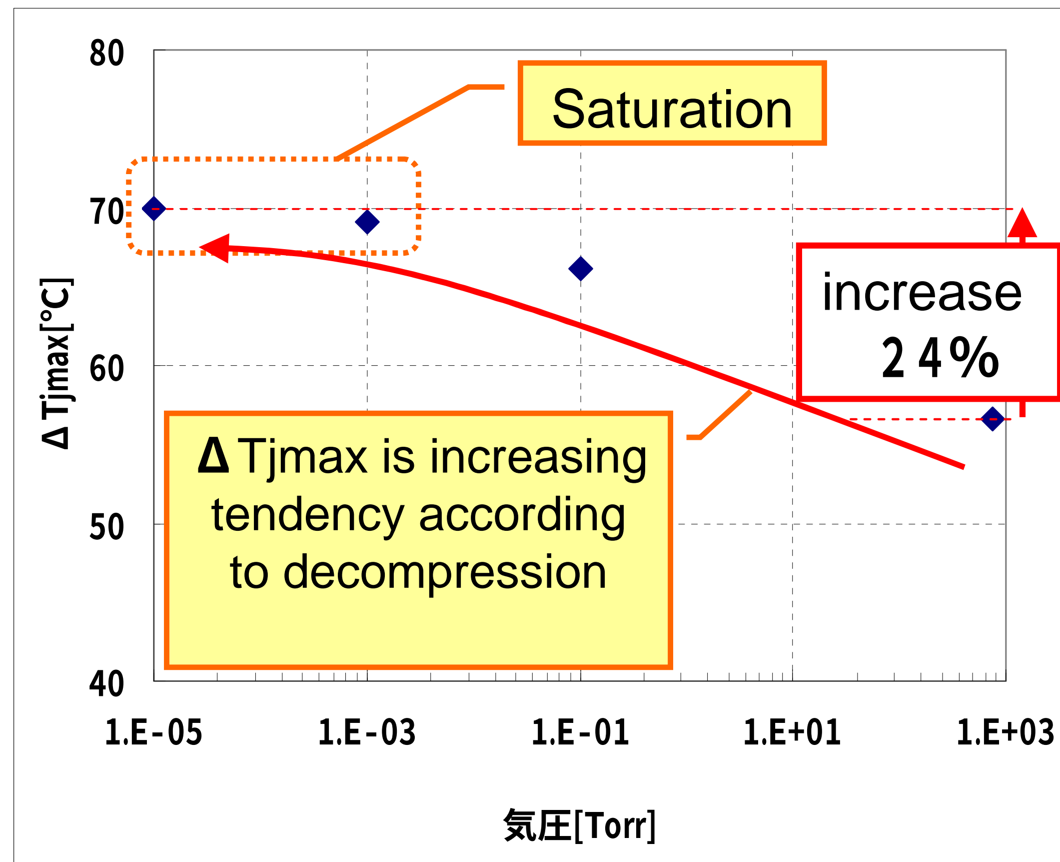
Thermal transient characteristics analysis under decompression condition

～ Results (Temperature change) ～

●Temperature change



	1E+3 Torr	1E-1 Torr	1E-3 Torr	1E-5 Torr
ΔTjmax [°C]	56.59	66.14	69.15	69.96



ΔTjmax increases by about 24% under the decompression condition compared with the atmospheric pressure. The thermal resistance in data sheet is the thermal resistance in the atmosphere and it is including the thermal released from the package surface part usually. It is necessary to pay attention to the junction temperature rise because the thermal radiation from the surface of the package may decrease under the decompression condition.

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Thermal transient characteristics analysis under decompression condition ～ Conclusion ～

●The thermal transient characteristic analysis was executed under the decompression condition.

As a result, in the heat transient from the sample outside edge to the ambient environment being limited, and …

①Total thermal resistance increases.

②The thermal capacity in the molding resin decreases seemingly.

These were the results of suggesting being able to limit the directions of the heat transmission by decompression.

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Conclusion

●Explained the necessity and the principle of measurement of the thermal transient characteristic analysis.

Introduced the example of evaluating the LED light.

●The thermal transient characteristic analysis under the decompression condition was executed.

As a result, in the heat transient from the sample outside edge to the ambient environment being limited, and …

①Total thermal resistance increases.

②The thermal capacity in the molding resin decreases seemingly.

These were the results of suggesting being able to limit the directions of the heat transmission by decompression.

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