

Automotive MOSFET DSOP Advance(WF) Package Heat Dissipation Efficacy and Precautions When Mounting on a Board

Overview

This document describes the precautions when mounting DSOP Advance (WF) packages that can dissipate heat from the top and bottom of the package.

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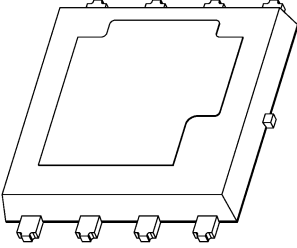
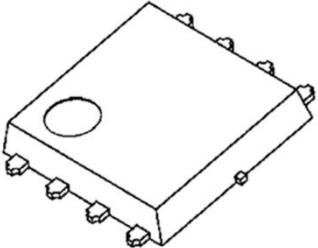
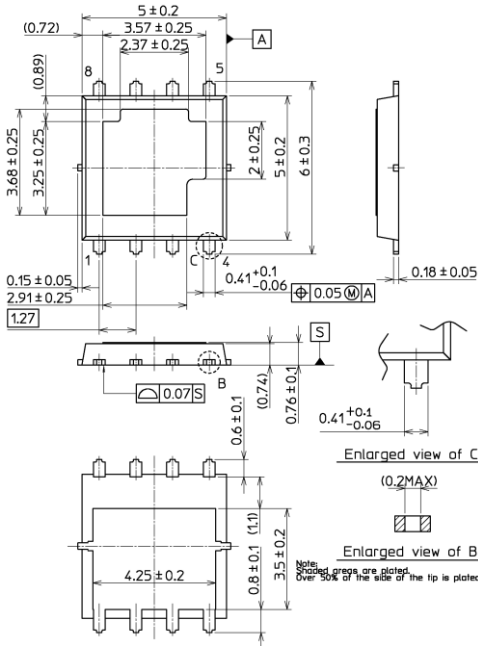
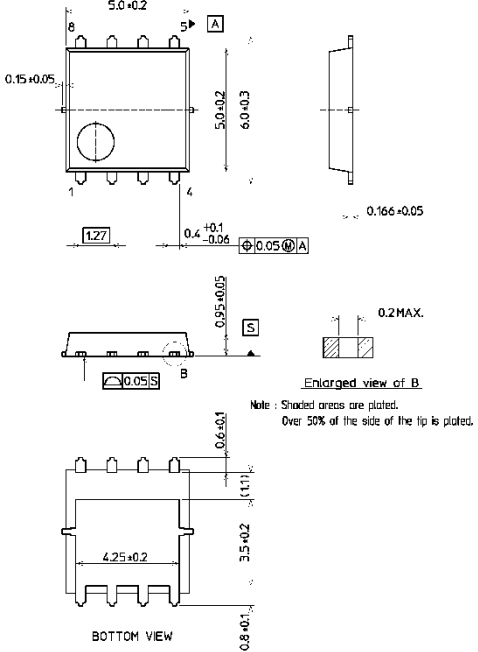
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1. Comparison of Packages (DSOP Advance(WF) and SOP Advance(WF))

Table 1-1 shows the main differences between DSOP Advance(WF) and SOP Advance(WF) which have the same package size. The DSOP Advance(WF) package has a heat sink that can dissipate heat from the top surface of the package as shown in the Perspective View in Table 1-1. This heat sink is called the "Top plate" (refer to Fig. 1.1).

Table 1-1 Package Comparison Table

	DSOP Advance(WF)	SOP Advance(WF)
Package Size	5.0mm×6.0mm×0.76mm (typical)	5.0mm×6.0mm×0.95mm (typical)
Wettable Flank (WF)	With	With
Top plate	With	Without
Perspective View		
External Dimensions		
Representative Products	TPWR7904PB	TPHR7904PB

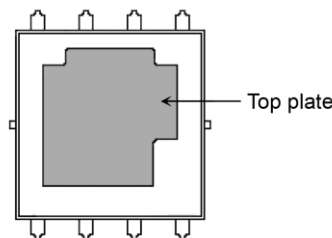


Fig. 1.1 DSOP Advance(WF) Top View

2. Precautions When Mounting DSOP Advance(WF) Package on a Board

DSOP Advance(WF) is equipped with a top plate. When using the top plate to dissipate heat, ensure that the external stress applied to the top plate of the is less than 10N.

When using Thermal Interface Materials (TIMs), such as thermal grease, between the heat sink and the top plate, make sure that the TIM will not affect the product, and no leakage current must be caused by the material.

This document introduces the heat dissipation method using the top plate and its efficacy, and the effect of TIM on the product. However, please note that this document is for reference only and does not constitute any warranty.

The top plate of the DSOP Advance(WF) product is not intended to be soldered to the heat sink.

The top plate of DSOP Advance (WF) products is plated, and after reflow mounting on a board, the top plate of DSOP Advance (WF) products may become uneven. This is caused by the solidification of molten plating during reflow mounting. Below is an example of how the top plate looks like after reflow mounting. Please take sufficient care in designing the clearance between the heat dissipating parts and the top plate.

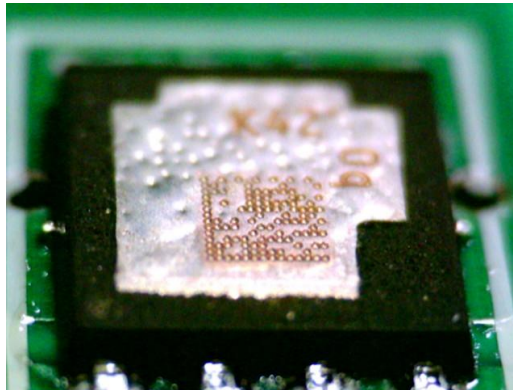


Fig. 2.1 View of the top plate after reflow (example)

Note:

When the body or a connecting part of the semiconductor product is subjected to vibration, impact, or stress in the actual set-up, bonding fault or device destruction may result. Therefore, sufficient consideration is needed in the mechanical design

If a semiconductor product is subjected to especially strong vibration, impact, or stress, the package or chip may crack. If stress is incurred by the semiconductor chip through the package, changes in the resistance of the chip may result due to piezoelectric effect. This can result to fluctuation in the characteristics of the product. Furthermore, if stress is applied continuously for a long period of time, product deformation may result. This can cause defects, such as disconnection or product failure.

Thus, at the time of mechanical design, vibration, impact, and stress must be carefully considered.

3. DSOP Advance(WF) Package Heat Dissipation Efficacy

3.1. Thermal Impedance Evaluation Overview

Representative products of DSOP Advance(WF) and SOP Advance(WF) were mounted on a board, and thermal impedances ($z_{th(ch-a)}$) were compared.

3.1.1. Evaluated Products

TPWR7904PB : DSOP Advance(WF), $V_{DSS}=40V$, $I_D=150A$, MOSFET U-MOSIX

TPHR7904PB : SOP Advance(WF), $V_{DSS}=40V$, $I_D=150A$, MOSFET U-MOSIX

3.1.2. Board Design

The boards used in this evaluation were designed as shown in fig. 3.1. The following were considered in the design of the board:

- Typical substrate materials used in automobiles
- Wiring pattern capable of applying current to the evaluated product

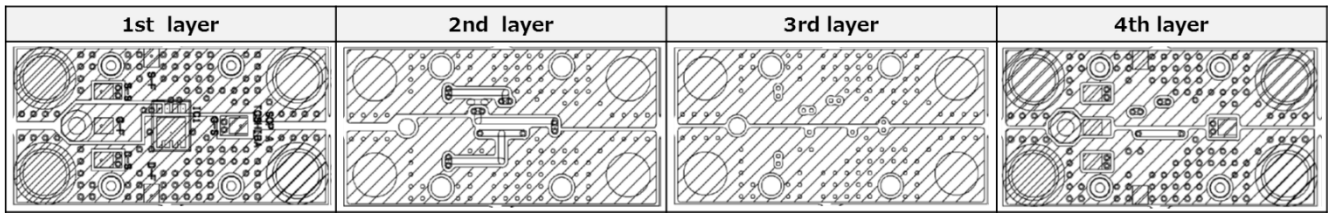


Fig. 3.1 Board Design Used in the Thermal Impedance Evaluation

Substrate material: Equivalent to FR-4

Board size: 2inch×1inch × 1.6mm 4-layer board

Copper foil thickness: 1st layer: 75 μ m, 2nd layer: 35 μ m, 3rd layer: 35 μ m, 4th layer: 75 μ m

Mounting solder mask thickness: 150 μ m

3.1.3. Land Pattern

Toshiba land pattern dimension drawings were used as reference for the land patterns.

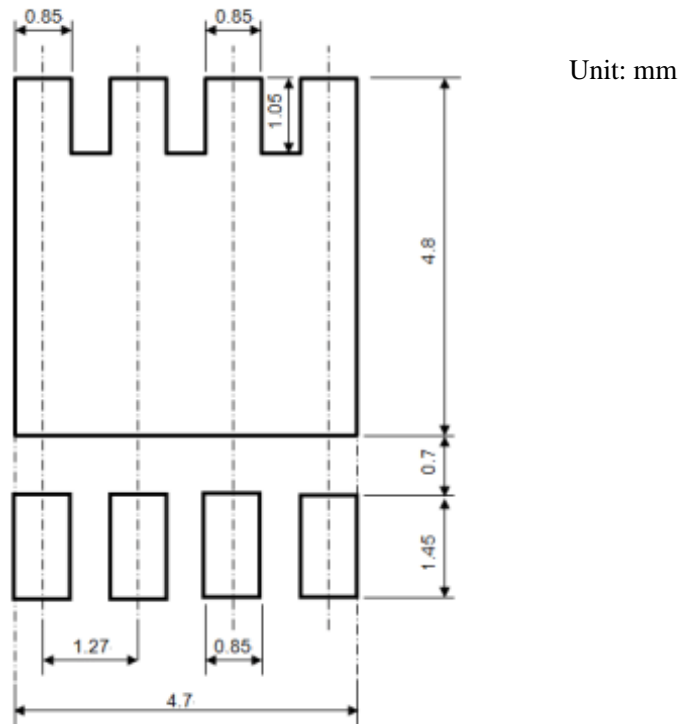


Fig. 3.2 SOP Advance(WF) and DSOP Advance(WF) Land Dimensions Reference

3.1.4. Mounting Condition

Fig 3.3 shows the mounting condition. For TPWR7904PB (DSOP Advance(WF)), TIM was used to attach the aluminum heat sink to the top plate (refer to Fig. 3.4). TIM was applied over the entire sample as expected in actual use.

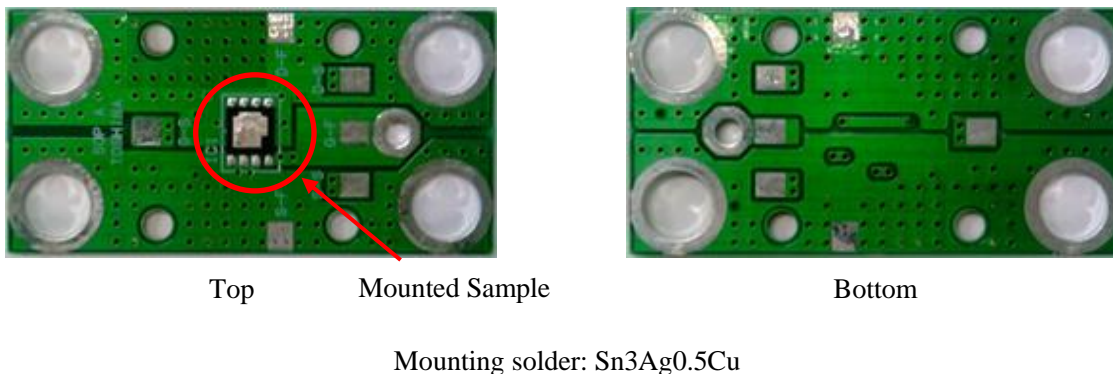
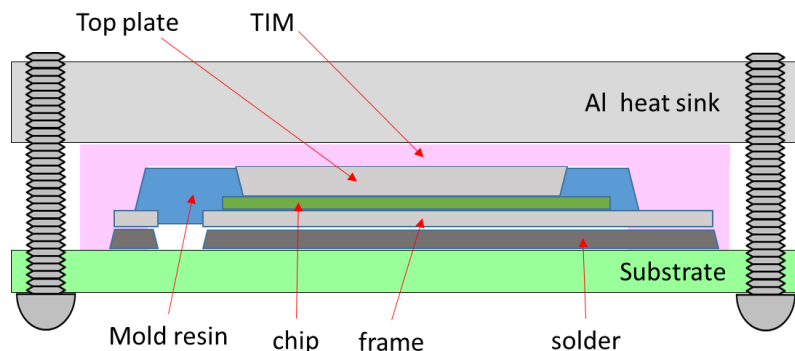


Fig. 3.3 Mounting of the Product for Thermal Impedance Evaluation



TIM: Hardening-type thermal grease (5W/m · K) manufactured by Denka Corporation

Fig. 3.4 Cross-section of DSOP Advance (WF) Mounting Condition

Fig. 3.5 and Fig. 3.6 show the mounting condition of SOP Advance(WF), and DSOP Advance(WF) with aluminum heat sink, respectively. Thermal impedance from the board only (for SOP Advance (WF) package), and from both aluminum heat sink and the board (for DSOP Advance (WF) package) were compared.

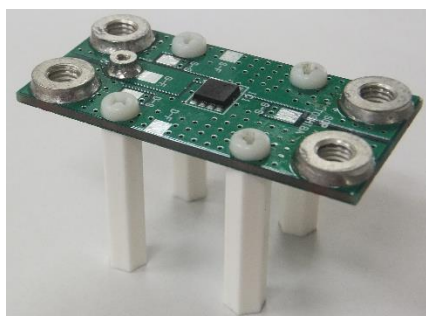


Fig. 3.5 Heat Dissipation from Board Side Only for SOP Advance(WF)

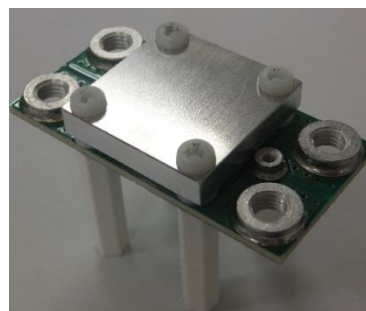


Fig. 3.6 Heat Dissipation from Both Aluminum Heat Sink and Board for DSOP Advance(WF)

3.2. Results

Fig. 3.7 shows that by attaching the heat sink to the top plate, the DSOP Advance (WF) package has a better thermal impedance as compared to SOP Advance (WF) package that has no top plate.

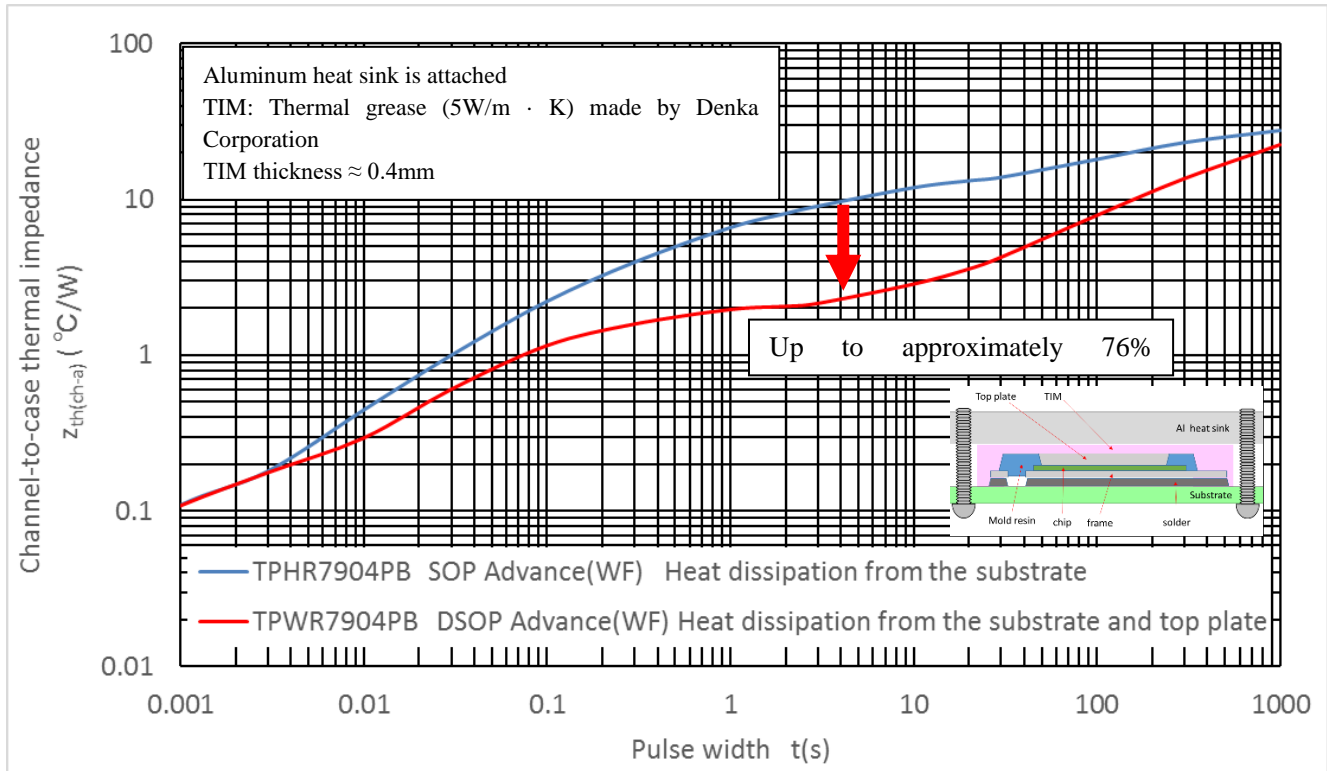


Fig. 3.7 Improvement of Thermal Impedance When Top Plate is Used and a Heat Sink is Attached

3.3. Comparison of Thermal Impedance with Different TIM Thickness

The effect of changing the distance between DSOP Advance(WF) top-plate and the heat sink (and the thickness of TIM) on the heat dissipation properties was confirmed.

3.3.1. Evaluation Materials

In order to make a more effective comparison of the effects of the heat sink, the board shown in Fig. 3.8, which is smaller than the board described in Chapter 3.1.2, was used for evaluation.
 For the board, a material equivalent to FR-4 was used, and for the TIM, a non-hardening type was used.

- Substrate material: Equivalent to FR-4
- Board size: 1inch×1inch × 1.6mm 4-layer board
- Copper foil thickness: 35µm in all layers
- Mounting solder mask thickness: 150 µm
- TIM: Thermal grease (5.1W/m · K) non-hardening type

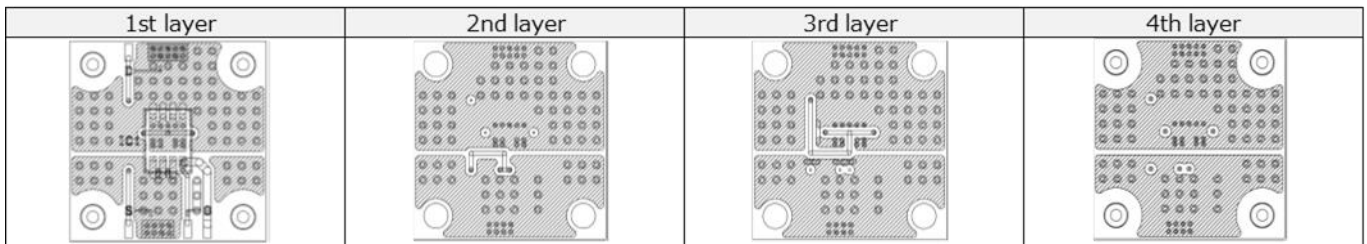


Fig. 3.8 Board Design Used in the Evaluation of the Effect of TIM thickness to the Thermal Impedance

3.3.2. Thermal Impedance with Different TIM Thickness Evaluation Results

Fig. 3.9 indicates that from 0.1s to 200s pulse width, the thinner the TIM layer, the smaller the thermal impedance is. In addition, Fig. 3.10 shows the dependence of thermal impedance to TIM thickness at t=3s.

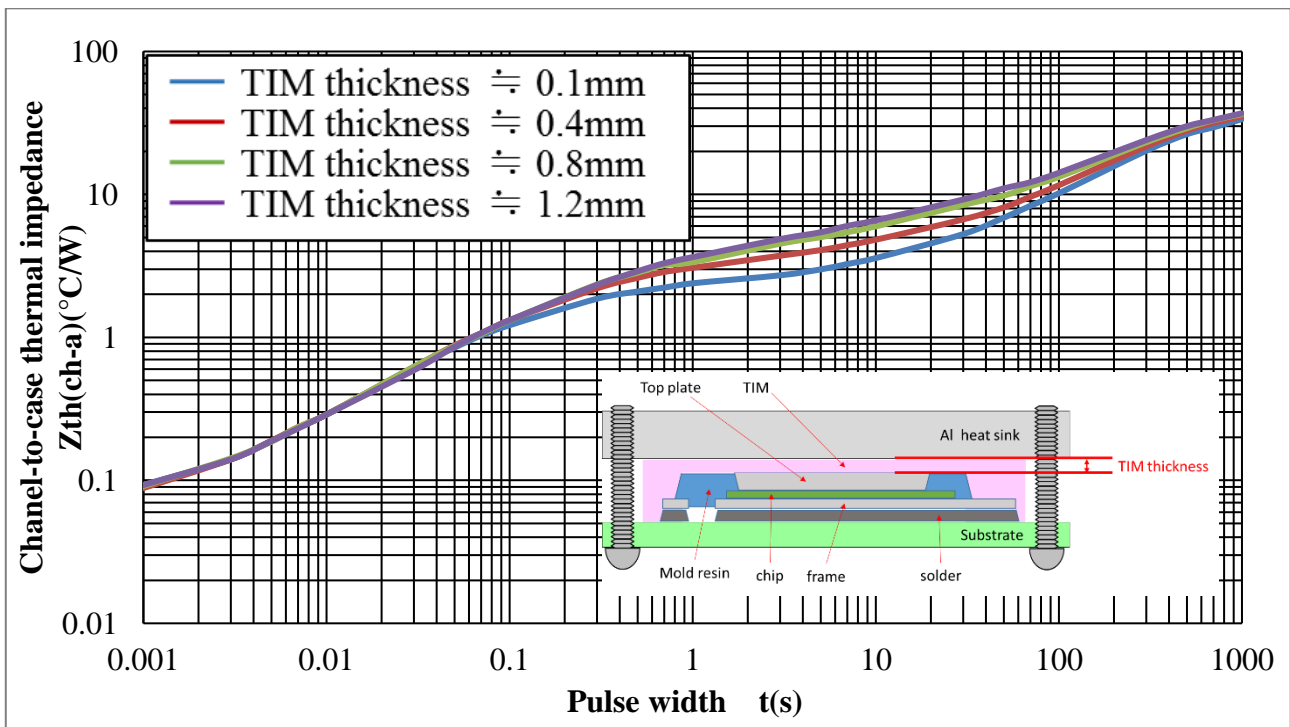


Fig. 3.9 Thermal Impedance with Different TIM thickness Evaluation Result

As shown in fig. 3.10, the thermal impedance decreased by about 45% when the TIM thickness was changed from 1.2mm to 0.1mm. By thoroughly examining the TIM and other peripherals, and by keeping the amount of TIM as thin as possible, the thermal impedance can be reduced.

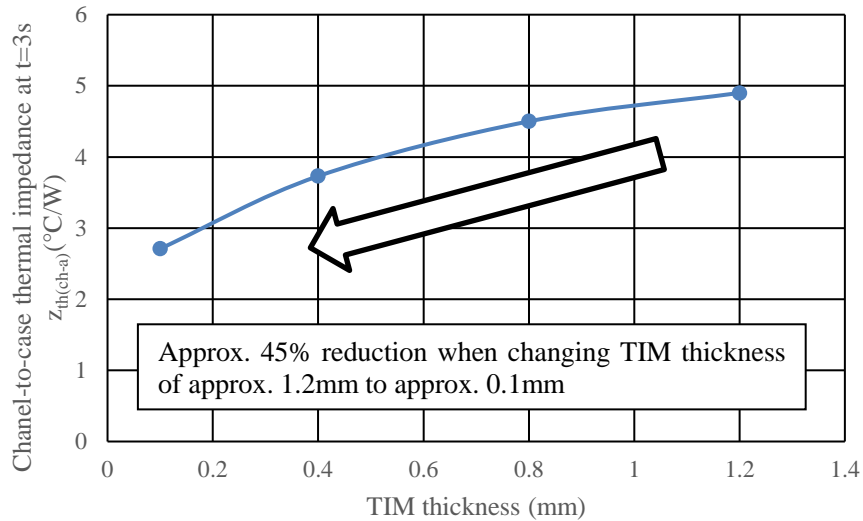


Fig. 3.10 Dependence of Thermal Impedance on TIM Thickness

Note:

For actual design, determine the TIM thickness based on variations in dimensions and dielectric strength. For precautions on heat dissipation design, refer to the following application notes: "Hints and Tips for thermal Design" "Hints and Tips for thermal Design part2", and "Hints and Tips for thermal Design part3".

4. Confirmation of Reliability When Mounted on a Board

4.1. Reliability Test Evaluation Overview

Temperature Cycle Test was conducted to confirm if the thermal stress does not lead to device failure. Pressure Cooker Test (PCT) and High-Temperature and High-Humidity Biasing Tests (THB) were also conducted to confirm if chemical effects (chemical attacks) from TIM-containing materials do not lead to device failure.

4.2. Materials Used

4.2.1. Evaluated Product

TPWR7904PB : DSOP Advance(WF), $V_{DSS}=40V$, $I_D=150A$, MOSFET U-MOSIX

4.2.2. Thermal Interface Materials (TIMs)

TIM_A: Thermal grease manufactured by Denka Corporation (5W/m · K)

TIM_B: Thermal grease manufactured by Co. A (5.1W/m · K)

TIM_C: Thermal grease manufactured by Co. B (4.0W/m · K)

* All three TIMs were evaluated at TIM thickness $\approx 0.4mm$.

4.2.3. Mounting Solder

Solder: Sn3Ag0.5Cu

4.2.4. Mounting Condition

Fig. 4.1 shows the mounting condition of the sample after the aluminum heat sink was attached using a TIM. The board used in Chapter 3.1.2 was also used in this evaluation, and the construction of the sample is the same as in Chapter 3.1.4. TCT was performed while the board was facing down.

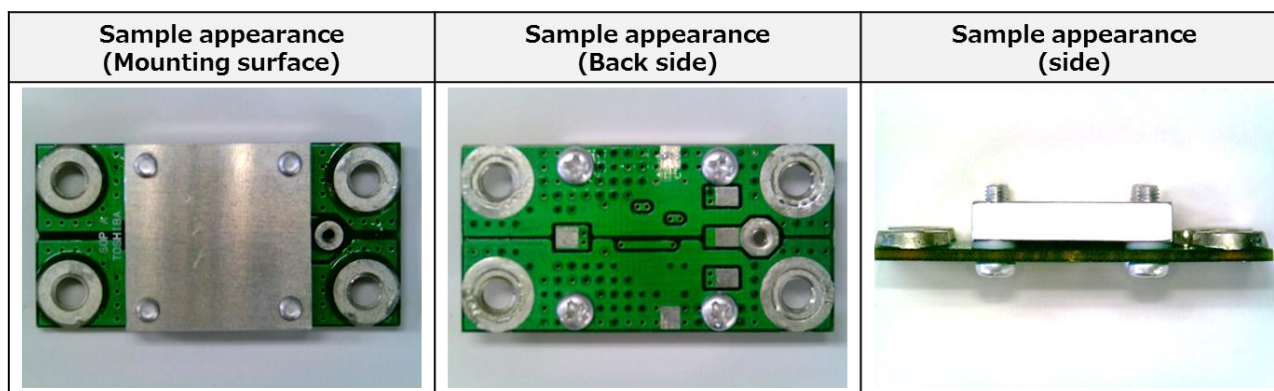


Fig. 4.1 Mounting Condition of Test Sample on DSOP Advance(WF) TCT Board

4.3. Reliability Test Evaluations Conditions

Table 4-1 Reliability Test Evaluations Conditions

Test item	Test conditions	Evaluation time / Number of cycles	Use TIM	Test Number of samples	Failure criteria
TCT	Gas phase, Ta=-40°C to 125°C Temperature retention time is 20 minutes. No temperature gradient control	3000cycle	TIM_A	22pcs	Table 4-2 Failure Judgment Criteria
			TIM_B	22pcs	
			TIM_C	22pcs	
THB	Ta=85°C, Rh=85% V _{DS} = 40 V (100% rated voltage)	2000 hours	TIM_A	22pcs	
			TIM_B	22pcs	
			TIM_C	22pcs	
PCT	203 to 255kPa Rh=100%	192 hours	TIM_A	22pcs	
			TIM_B	22pcs	
			TIM_C	22pcs	

4.4. Failure Criteria

Failure was assessed in reference to the AEC Standard, AEC-Q101 rev-D1, made by the Automotive Electronics Council, an in-vehicle electronic device reliability certification organization in the United States. Failure judgment criteria are shown in Table 4-2.

Table 4-2 Failure Judgment Criteria

	Gate leakage current	Drain cut-off current	Drain-sources breakdown voltage	Gate threshold Voltage	Drain-sources on-resistance
	$\pm I_{GSS}$	I_{DSS}	$V_{(BR)DSS}$	V_{th}	$R_{DS(ON)}$
TCT	Within 5 times initial (*), and Data sheet specifications shall not be exceeded.		Within $\pm 20\%$ of initial variation, and Data sheet specifications shall not be exceeded.		
THB	Within 10 times initial (*), and Data sheet specifications shall not be exceeded.				
PCT					

* For gate leakage current and drain cutoff current, if the initial value is 100nA or less, the initial value will be 100nA, and the failure judgment value is obtained by multiplying 100nA by the scaling factor shown in the table.

4.5. Reliability Tests Results

As shown in Table 4-3, no defects were identified per TIM.

Table 4-3 Reliability Test Results

Test item	TIM used	Number of failures/number of samples
TCT	TIM_A	0/22pcs
	TIM_B	0/22pcs
	TIM_C	0/22pcs
THB	TIM_A	0/22pcs
	TIM_B	0/22pcs
	TIM_C	0/22pcs
PCT	TIM_A	0/22pcs
	TIM_B	0/22pcs
	TIM_C	0/22pcs

Note:

The results of these tests are for reference only, and all mounting methods and materials were not verified.

4.6. Appearance Check (Additional check)

Surfaces and cross-sections of the solder joints were observed to check for cracks after TCT, and it was confirmed that the solder joints had no significant defects when the aluminum heat sink was attached using a TIM.



Fig. 4.2 Solder Condition After 3000 cycles of TCT

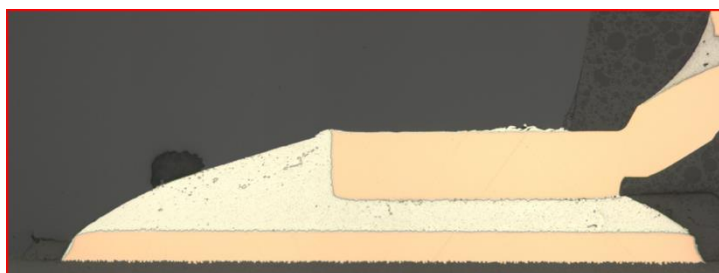


Fig. 4.3 Cross-section of Terminals after 3000 cycles of TCT

Notes on Contents**1. Evaluation Results**

The results found in this document are for reference purposes only.

2. Charts and tables

Some illustrations, tables, etc. were omitted for explanatory purposes.

3. Materials used for evaluation

Some parts and materials used for evaluation were omitted for explanatory purposes.

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