Pre-Applied phase change Thermal Interface Material 2.0

Infineon EasyPACK™, EasyPIM™ and EasyDUAL™ 1 and 2 products

About this document

Scope and purpose

The Infineon EasyPACK™, EasyPIM™ and EasyDUAL™ 1 and 2 products now offer an optional phase-change thermal interface material, TIM 2.0. This new material features improved performance, reliability, and efficiency. This application note explains the benefits and applications of TIM 2.0.

Intended audience

The intended audiences for this document are design engineers, technicians, and developers of electronic systems.

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1 General information

The increasing demand on power density in the power electronics pose growing challenges for the thermal interface between the power semiconductor modules and the heat sink. Different types of Thermal Interface Materials (TIM), such as Phase-Change-Materials (PCM), are used to ensure an efficient heat transfer at the interface between the power module and the heat sink. In this case, any voids and irregularities between the mating surfaces can be filled with this material.

The TIM can contribute up to approximately 60% of the total thermal resistance. Therefore, the selection of the appropriate material plays a fundamental role and become a huge challenge for the user, particularly when long-term stability is required for the application.

In this context, Infineon now offers a new TIM (2.0) that meets these requirements for a wide range of applications. It exhibits outstanding wetting properties, making it suitable for application demanding higher performance and offers a significant value add to customer products.

However, to fully exploit the advantages of this TIM, it is of great importance to follow the corresponding handling instructions and the portfolio of the pre-applied TIM 2.0. The Application Note describes the use and the handling of power modules with the factory applied TIM in the following chapter.

1.1 Nomenclature and portfolio of the pre-applied TIM 2.0

The TIM 2.0 is available in combination with the EasyPACK™, EasyPIM™ and EasyDUAL™ products. Due to its special characteristics, it will be pre-applied using the stencil printing process. This eliminates the need for customers to apply it themselves. It simplifies the assembly process, reduces production time, and minimizes the risk of errors on customer side. The TIM 2.0 is our standard PCM for future EasyPACK™ and EasyPIM™ 1 and 2 products. All our existing EasyPACK™, EasyPIM™ and EasyDUAL™ 1 and 2 products from the B series are still available with pre-applied TIM 1.0. Upon customer request, the existing EasyPACK™, EasyPIM™ and EasyDUAL™ 1 and 2 products can also be offered with TIM 2.0. These products are designed to provide optimal thermal management solutions for various applications, ensuring improved performance, reliability, and efficiency.

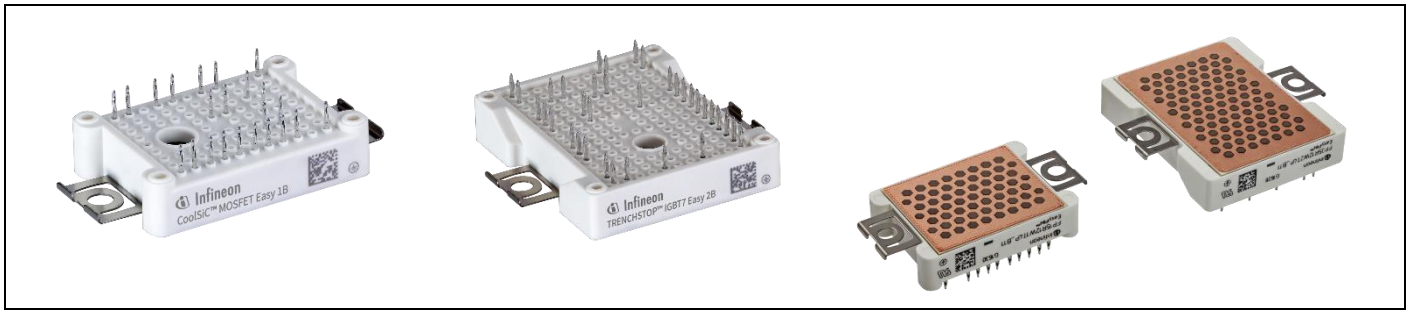

Figure 1 EasyPACK™ B series

To facilitate easy identification of products that utilize the advanced TIM 2.0 technology, Infineon has introduced the letter “Q” in the product names. This notation allows customers to quickly identify which products feature the pre-applied TIM 2.0 version, making it easier for them to select the right product for their specific application requirements.
In the following example, the letters for TIM modules are explained:

- FP15R12W1T4 → without TIM
- FP15R12W1T4P → TIM 1.0
- FP15R12W1T4Q → TIM 2.0

2 Technical information

2.1 Thermal Interface Material (TIM) 2.0

The TIM 2.0, originally known as PTM6000HV-SP, is a PCM with a polymer structure, that undergoes a phase change from solid to soft, once a temperature, typically above 45°C, is exceeded. Below the melting temperature it maintains wax-like consistency. In order to ensure a complete phase change within the entire material, Infineon recommends the TIM to go beyond a temperature of 60°C once after assembly.

A key benefit of this material lies in its enhanced thermal performance, achieved through to the high thermal conductivity and excellent wetting properties. These characteristics optimally reduce the contact resistance. Despite the high thermal conductivity, it has a high resistance to pump-out, even when power modules mounted vertically. This high stable performance could also be validated through a series of reliability tests, which will be discussed in the subsequent sections.

The main important characteristics of PTM6000HV-SP are listed in following Table 1. For more details, please refer to the datasheet from the manufacturer.

Parameter	Value	Unit
Thermal conductivity	5.2	$W/m \cdot K$
Specific gravity	2.6	g/cm^3
Volume resistivity	2.1x10^{14}	$\Omega \cdot cm$
Phase-change temperature	> 45	°C
Continuous operating temperature limit	150	°C
Viscosity above phase-change temperature	Thixotropic	
Color	Gray	

Table 1 Properties of PTM6000HV-SP

2.2 Storage of TIM 2.0 modules

The pre-applied TIM 2.0 products will be delivered in special protective packing. To avoid impacting the performance and lifespan of these products, these must be stored in the original packing according to the following conditions, in Table 2. Please, avoid any external contact with the pre-applied PCM.

Parameter	Value	Unit
Temperature	5 < T < 40	$°C$
Relative humidity	10 < rh < 65	%
max storage time	12	$months$

Table 2 Storage conditions of the products with pre-applied TIM 2.0

In case the maximum storage time of 12 months is exceeded, the TIM 2.0 should be removed from the module and replaced with a new thermal grease before is installed and used in an application. For more information regarding the removal process, please refer to the following Application Notes:

- Application Note AN 2012-07 “Mounting to a heat sink” for the cleaning process [1]
- Application Note AN 2006-02 “Application of thermal compound” for the application process [2]

Note: The application process described in AN 2006-02 is based on an EconoPACK™ 3 module but can also be applied to modules without a base plate. Please follow the specified processes to ensure proper removal of TIM 2.0 and application of an alternate grease.

2.3 Reliability tests of the TIM2.0

Infineon conducts a series of reliability tests to ensure the reliability of the modules and verify its performance under various environmental conditions. In the following, the reliability tests to ensure the reliability of the TIM 2.0 with our modules are considered and listed below:

- **Power cycling test (PC)** [3]: This PC test was used to evaluate the reliability and service life of the pre-applied TIM 2.0 under repeated current cycles. Power cycling is explained in AN 2019-05. The aim is to simulate the loads that occur under real conditions and to determine any noticeable material deterioration, such as pumping out.
- **High-temperature reverse bias** [4]: In this HTRB test, limit sample modules with TIM 2.0 are examined. After baking out, solvent is released from the TIM. The test checks whether the components of the module are affected by high temperatures or an increased proportion of solvent. If there is no impairment, the module passes.
- **Humidity test** [5]: This humidity test was conducted to evaluate the ability of the TIM 2.0 to withstand high humidity without affecting the material properties. The TIM 2.0 was exposed to controlled high humidity to simulate the effects on the Rth and components.

- **Vibration test** [6]: The purpose of this vibration test was to evaluate the resistance of the TIM 2.0 to mechanical vibrations that are common in many applications. The TIM 2.0 was subjected to a controlled vibration profile to determine that the TIM does not leak.
- **Temperature shock test (TST)** [7]: The aim of this TST was to determine the resistance of TIM 2.0 to thermomechanical shocks that occur in many applications. In this test, the TIM 2.0 was subjected to a controlled shock profile to see whether a pump-out of the TIM and a ceramic crack could occur. If there is no pump-out and no ceramic crack during the test, then the test is passed.
- **Life-cycle test**: This test was specially developed to simulate the entire lifetime of the TIM 2.0 and to evaluate its reliability and performance over a longer period of time. In this specially developed test, the module with the TIM 2.0 is stored at a high temperature and then run in continuous operation to reproduce the ageing process of the TIM more quickly. The module is then thermally cycled to be able to assess the lifetime based on the Rth. This test simulates the real operation of the module with the TIM.

The results from these tests have shown that the TIM 2.0 meets the required reliability standards for use in various applications.

2.4 Handling instruction of TIM 2.0

When working with the TIM 2.0, it is important that you follow the correct handling rules. The TIM 2.0 is sensitive to environmental influences such as temperature, humidity and mechanical stress. In case the TIM is not handled correctly, this can lead to a deterioration in its performance, which in turn can lead to increased component temperatures and possibly to system failure. Damage to the material can be avoided by correct handling. Some guidelines to follow are:

- Wear clean, dry gloves when handling TIM 2.0 to prevent contamination.
- Avoid external contact to the TIM 2.0 surface so that any contamination from the skin does not affect its performance.
- Use a soft, dry brush to remove any dirt or dust from the surface of TIM 2.0.
- Avoid exposing TIM 2.0 to direct sunlight or high temperature.
- It is recommended using a protective cover to the surface of the TIM 2.0 paste, so that contamination or scratches during the press-in process can be prevented.

Following these guidelines will ensure that the performance of TIM 2.0 is not compromised.

2.5 The solder, press-in and press-out processes

The press-in and press-out processes are crucial steps in the assembly of TIM 2.0 modules. They require careful handling to achieve the optimal results. It is important to utilize the correct tooling and follow the recommended procedure to prevent damage, ensure proper alignment, and maintain the integrity of the TIM 2.0 material.

2.5.1 Solder

The soldering tools required for the assembly of EasyPACK™ modules are described in the Application Note - AN 2005-06 “Soldering of EconoPACK™, EconoPIM™, EconoBRIDGE™, EconoPACK™+, EconoDUAL™, EasyPACK and EasyPIM™ modules” described in detail [8]. This application note contains step-by-step instructions for the soldering process for mounting modules in a printed circuit board (PCB). These processes can also be used for modules with TIM. Care must be taken to ensure that the TIM material is not damaged and that the temperature of the material does not exceed 45°C. Otherwise, higher thermal resistance ($R_{th,j\text{-}h}$) values may occur during operation, increasing the risk of failure.

2.5.2 Press-in

The press-in tools required for the assembly of EasyPACK™ modules with TIM are comprehensively detailed in the Application Note – AN 2009-01 “Press-in tools for EasyPACK™ modules with thermal interface material (TIM)” [9]. This Application Note provides step-by-step guidance on the press-in process for mounting modules with TIM into a printed circuit board (PCB) in the section “Press-in process of a module with thermal interface material (TIM)”.

2.5.3 Press-out

The press-out process, using appropriate tools, is crucial to prevent any damage to the PCB and the module. Detailed information on the correct tools and procedure for safely removing the module from the PCB is available in the application note AN 2009-01, specifically in the section “The press-out process” [9]. In Case that the module has previously been detached from a heat sink, the used TIM must be removed and a fresh thermal grease applied so that the module can be reused.

2.6 First commissioning of TIM 2.0

The first commissioning of the TIM 2.0 is a crucial step to ensure the reliable operation of the thermal management system. During this process, the TIM is undergoing to a controlled temperature profile to activate its thermal interface properties. Adhering to the recommended procedures is essential to prevent damage the material. By carefully controlling the temperature profile, the TIM can be optimized for maximum performance, ensuring effective thermal management and reliable operation of the system.

The TIM 2.0 changes its state from solid to liquid at a phase change temperature of about 45°C. The thermal resistance (R_{th}) of the TIM is higher at the beginning due to the poor wetting and the resulting poor thermal contact resistance. However, this is not critical, as the heat sink temperature remains below 45°C and the junction temperature is well within a safe operation range. As soon as, the temperature of the PCM is exceeding the 45°C and the material changes its state, the thermal resistance improves. Therefore, it is recommended to plan the final test of the equipment in duration and load so that a smooth and complete phase transition from solid to liquid is achieved. For this purpose, the temperature of the PCM between the DCB and heat sink should exceed a temperature about 60°C for a duration of at least 5 - 10 minutes.

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Please note that the duration may vary depending on the set operation and cooling conditions.
In most fan cooling applications, the steady state of the entire system is not reached within this time range, because of the high thermal capacity of heat sink. Therefore, it must be considered, that the junction temperature may be higher during the field operation than in the test, depending on set parameters in the test.

During field operation the R_{th} may continue to improve over time due to the thermal cycling. Since the material gradually changes its state from liquid to solid back, once the heat sink temperature is lower than 45°C, it's very resistant to complete pump out, even in vertical state conditions.

3 Good prints of TIM 2.0 paste on the baseplate-less modules

The standards for controlling and monitoring the application process of the TIM on the modules are very high in our production. Nevertheless, there may be minor deviations in the imprint image of the TIM. For example, individual honeycombs may show discoloration or small amounts of TIM on the edges. The "Good parts - overview" section of the application note AN 2012-07 provides images that show these and other minor deviations in the print image [1]. These deviations have no influence on the thermal performance of the baseplate and the baseplate-less modules.

References

[1] [Infineon Technologies AG]: [AN 2012-07 Modules with preapplied thermal interface material]; [Munich]; [Infineon Technologies AG]; [2017-01]; [https://www.infineon.com/dgdl/Infineon-AN2012_07_Modules_with_pre_applied_Thermal_Interface_Material-AN-v02_01-EN.pdf?fileId=db3a30433af3614c013af3c70cf10025]

[2] [Infineon Technologies AG]: [AN 2006-02 Using screen-printing templates to apply thermal grease in IGBT modules]; [Munich]; [Infineon Technologies AG]; [2021-12]; [https://www.infineon.com/dgdl/Infineon-AN2006_02_Application_of_screen_print_templates-ApplicationNotes-v01_10-EN.pdf?fileId=db3a304412b407950112b40ed3f71297]

[3] [INTERNATIONAL ELECTROTECHNICAL COMMISSION]: [Semiconductor devices – Mechanical and climatic test methods – Part 34: Power cycling]; [IEC 60749-34]; [INTERNATIONAL ELECTROTECHNICAL COMMISSION]

[4] [INTERNATIONAL ELECTROTECHNICAL COMMISSION]: [Semiconductor devices - Part 9: Discrete devices - Insulated-gate bipolar transistors (IGBTs)]; [IEC 60747-9]; [INTERNATIONAL ELECTROTECHNICAL COMMISSION]

[5] [INTERNATIONAL ELECTROTECHNICAL COMMISSION]: [Semiconductor devices - Mechanical and climatic test methods - Part 5: Steady-state temperature humidity bias life test]; [IEC 60749-5]; [INTERNATIONAL ELECTROTECHNICAL COMMISSION]

[6] [INTERNATIONAL ELECTROTECHNICAL COMMISSION]: [Environmental testing - Part 2-6: Tests - Test Fc: Vibration (sinusoidal)]; [IEC 60068-2-6]; [INTERNATIONAL ELECTROTECHNICAL COMMISSION]

[7] [INTERNATIONAL ELECTROTECHNICAL COMMISSION]: [Semiconductor devices - Mechanical and climatic test methods - Part 25: Temperature cycling]; [IEC 60749-25]; [INTERNATIONAL ELECTROTECHNICAL COMMISSION]

[8] [Infineon Technologies AG]: [AN2005-06 Soldering of EconoPACK™, EconoPIM™, EconoBRIDGE™, EconoPACK™+, EconoDUAL™, EasyPACK and EasyPIM™ modules]; [Munich]; [Infineon Technologies AG]; [2024-10]; [https://www.infineon.com/dgdl/Infineon-AN2005_06_Soldering_of_Econo_and_Easy-ApplicationNotes-v01_01-EN.pdf?fileId=db3a304412b407950112b40ed59e129a]

[9] [Infineon Technologies AG]: [AN2009-01 Assembly Instructions for the Easy Modules]; [Munich]; [Infineon Technologies AG]; [2023-08]; [https://www.infineon.com/dgdl/Infineon-AN2023-07_Assembly_Instructions_for_the_Easy_Modules-ApplicationNotes-v01_00-EN.pdf?fileId=db3a30431ed1d7b2011ef425e7c75c5c]

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