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AN-4186

F1 and F2 Modules with Pre-applied Phase Change Material (PCM)

Abstract

Addressing the need to improve the heat extraction from power devices and the thermal path to the heat sink, Phase Change Materials (PCM) has been introduced over the years. These materials can be pre-applied to the power package base or to the heat sink alternatively and by that allow users of such power devices to reduce the assembly effort. Extensive testing has shown that PCM materials provide a long term reliable cooling solution.

Fairchild offers PCM pre-applied modules in accordance with customer needs. Investigations including the selection of the best PCM, its application and reliability have been carried out for F1 and F2 modules and optimum functionality with good performance was achieved. This document provides the handling and application guide for PCM pre-applied F1 and F2 modules.

Alternatively, it is also possible for users to apply PCM to power modules themselves. Also provided is information about the application of the material to F1/F2 modules.

Introduction

PCMs are printed to the back of the substrate or base-plate of the power package. After drying in a temperature process it is in a solid (dried) state below the phase change temperature. This allows shipping the PCM pre-applied modules to the final assembly site. While the device heats up during operation, the PCM changes state from a solid to a soft phase above its phase change temperature. In the soft state, PCM spreads out to balance surface roughness or unevenness and preventing air inclusions to provide good thermal contact between the heat sink and the power part. If the temperature goes below phase change temperature, the PCM changes to its solid phase again.

By changing of phase without volume decreasing during operation of a module, the PCM plays a key role to maintain a stable thermal behavior within operating temperature swing. Depending on the shape of the base and the mounting pressure of the modules to the heat sink an optimized PCM printing geometry is essential.

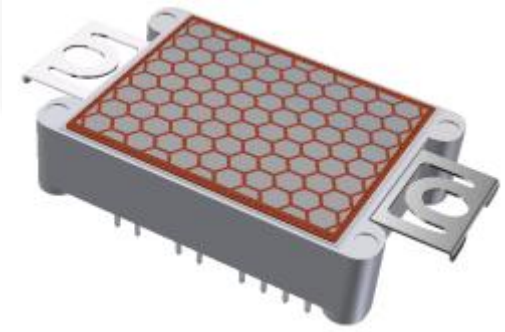


Figure 1. F1 Module

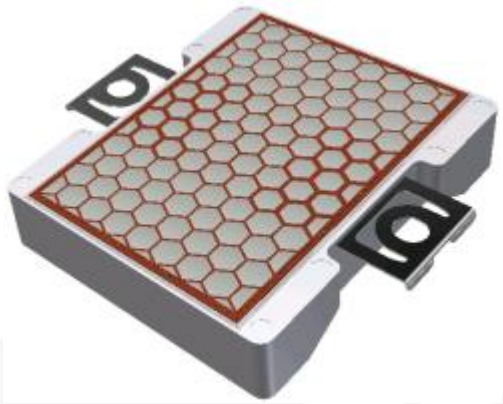


Figure 2. F2 Module

Key advantages of PCMs are listed below:

Benefits:

- Faster and easy application: cost and time saving at the assembly of an application
- Simple and clean handling in mounting and maintenance
- Provide optimized printing geometry: Accurate thickness control
- Achieve long working life and reliability: Low volume change (dry-out) over life time
- High Thermal Conductivity
- Spreading Characteristics: No pumping out
- Contamination free: Tack free at room temp.

Specification of PCM Printing for F1 and F2 Module

Characteristics of PCM

TCP 4000PM can be pre-applied to F1 and F2 module as per customer request. Characteristics of TCP 4000 PM are summarized in Table 1**.** Thermal conductivity is compatible with common thermal grease materials. PCMs keep good thermal performance without degradation after aging.

Table 1. Material Characteristics

Technology	Loctite TCP 4000 PM
Appearance	Grey
Phase Change Temperature (°C)	45
Required Pressure on the H/S (psi)	10
Thermal Conductivity (W/m*K)	3.4
Specific Gravity (g/cm^2)	1.81

Specification of PCM Printing Geometry

One of the benefits to use PCM pre-applied module is accurate Thermal Interface Material (TIM) thickness control. It is not easy to apply the optimum amount of TIM manually even the TIM thickness is crucial to the thermal performance. PCM pattern design of F1 and F2 are optimized through experimental verification. Considering the construction details a homogeneous honeycomb pattern is applied to F1 and a non-homogeneous honeycomb pattern is applied to F2, as shown in Figure 3**.**

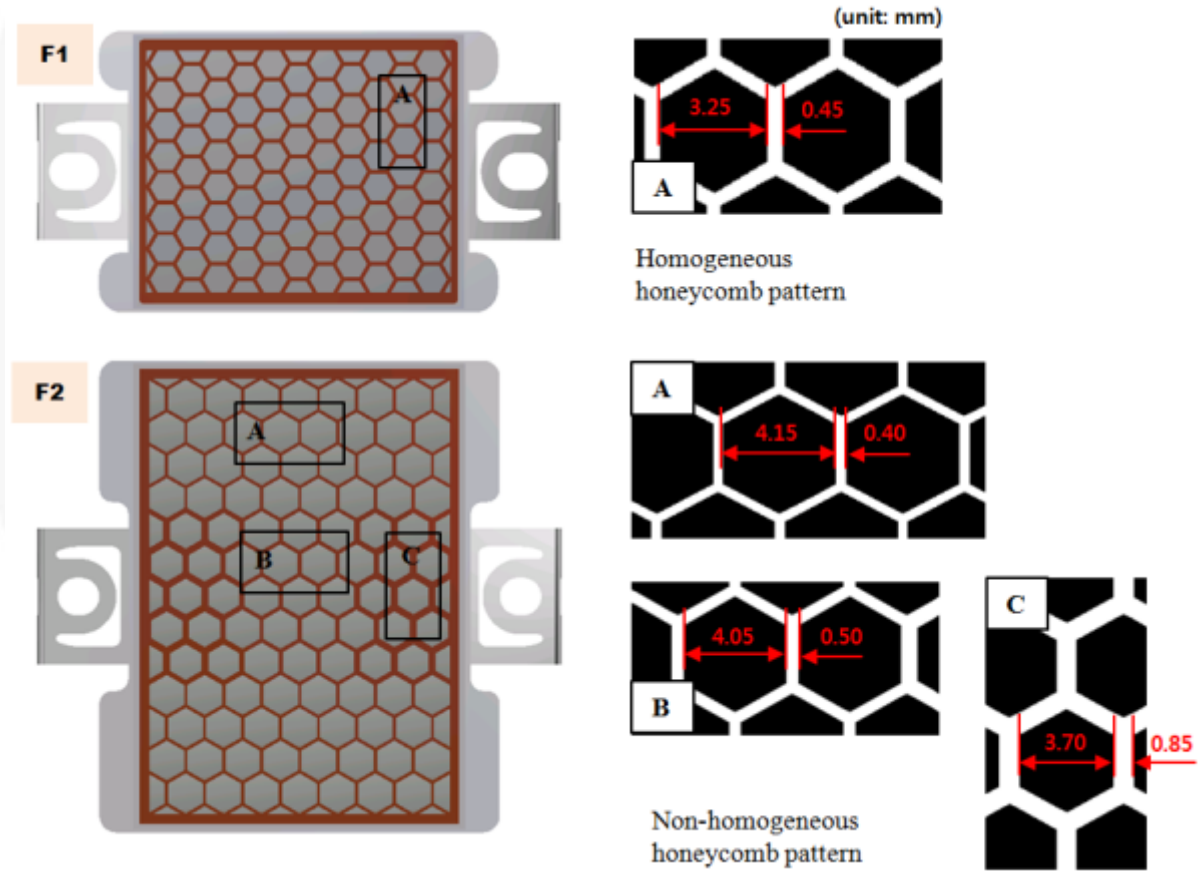


Figure 3. PCM Stencil Geometry Applied on F1 and F2 Modules

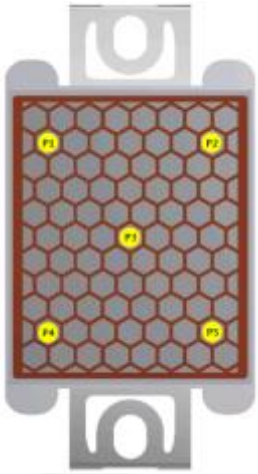


Figure 4. PCM Measurement Point: FI Module

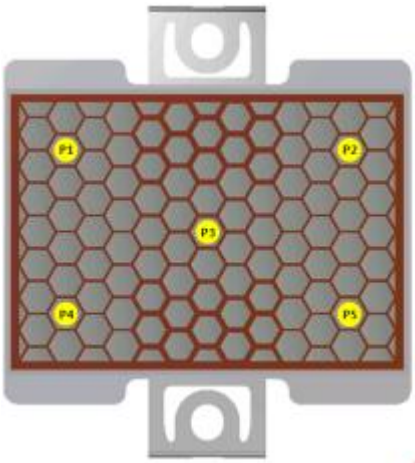


Figure 5. PCM Measurement Point: F2 Modules

Table 2. Specification of PCM Printing Layer

Pkg.	Printing Geometry	Min.	Typ.	Max.
F1	Applied PCM Weight (g)	0.114	0.122	
	Pattern to Pattern Spacing (mm)		0.50	0.58
	Honey Comb Thickness (µm)		80	
F2	Applied PCM Weight (g)	0.22	0.28	
	Clearance between Honey Comb (mm)		0.48	0.59
	Honey Comb Thickness (µm)		94	

Table 2 shows the printing geometry and weight information of PCM applied to the F1 and F2 module. Five local areas in a printing layer (see Figure 4 and Figure 5) were measured.

By calculation, the amount of PCM is around 67 mm^3 for F1 and 144 mm^3 for F2 modules. After PCM spreading above phase change temperature the corresponding final PCM layer thickness is 50 – 70 µm for both F1 and F2 modules. As shown in Figure 6 PCM spreads over the entire contact area after heating above the phase change temperature. The thermal performance was optimized through a distribution and thermal resistance tests. Pump out and dry out of material were not observed during operating, the PCM interface provides a stable performance and long-term reliability without thermal degradation. For the vertical (90°) mounting, it showed good performances over time without material pump out.

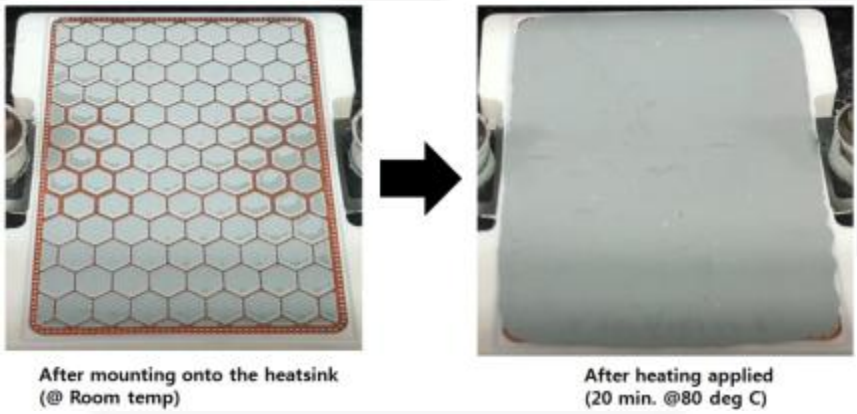


Figure 6. Appearance of PCM Distribution through Glass Inspection Block Under Phase Change Temperature

During operation of the module the PCM interface layer spreads out to fill the clearance between patterns and air gaps. This PCM settling process can potentially cause a loosening of the screws as described in Figure 7. In corresponding evaluations it was verified that the settling process does not require re-fastening of the mounting screws after initial operation. The package design with spring loaded metal clamps adjusts for the PCM distribution.

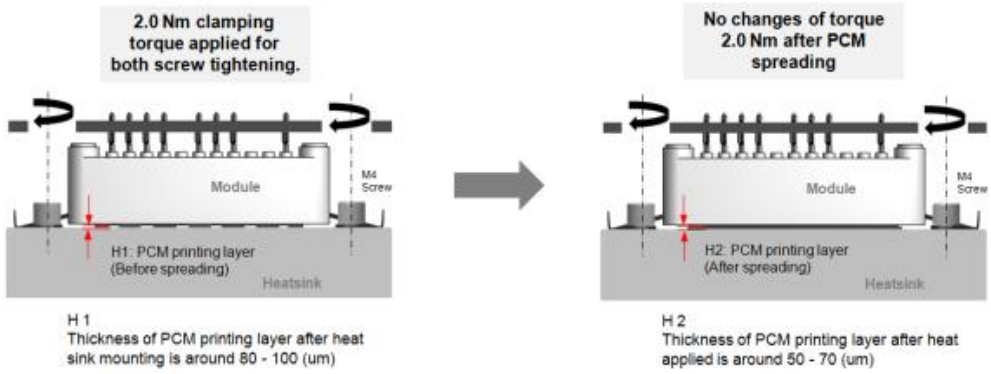


Figure 7. PCM Settling Process

Reliability

The reliability performance was verified in various environmental stress tests as listed in Table 3. The thermal resistance of the power devices does not increase after temperature cycling, high humidity, and high temperature test.

Reliability Tests with PCM Pre-applied Modules Modules

Reliability Tests	Conditions
Thermal Shock Test	1000cyc from -40°C to +125°C
High Humidity and High Temperature	1000h at 85% RH and 85°C
High Temperature Storage	1000h at 100°C

Mounting of PCM Pre-applied Module

By choice of the customer, F1 and F2 modules can be provided with solderable pins or press-fit pins. The same mounting technology can be applied to PCM pre-applied modules of the press-fit pin version as the modules intended to be used with thermal grease (usually applied after the process of mounting the module on the PCB). Depending on the mounting sequence, some design changes of press tool to protect PCM layer may be required.

Mounting into Printed Circuit Board (PCB)

Assembly in a Soldering Process

Several soldering technologies are applicable to modules for the assembly on a PCB. Usually wave soldering is a technology widely used for the soldering process. Potential risks of mechanical damages to the PCM layer during wave soldering process need to be considered. It is required to prevent mechanical damage to the PCM layer. This is needs to be considered also for the soldering process as high temperatures may cause the PCM layer to become soft. To prevent mechanical damages it is recommended to use special designed spacer jigs as shown in Figure 8.

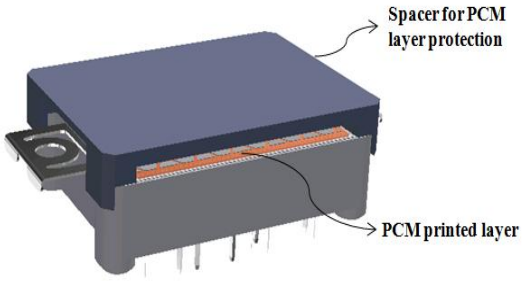


Figure 8. Example of Spacer to Protect PCM Printed Layer during Soldering Process

Assembly of Press-fit Pin Modules

If the module is mounted on the heat sink prior to the PCB assembly, no special precautions are required. The same standard mounting procedures and mounting tools described in AN-4167 are applicable for PCM pre-applied modules. If the mounting of the module to the PCB is done prior to the assembly on the heat sink, then a unique press-in tool is required to protect the PCM layer during the press-in process. Small damages to the PCM layer by press-in jig can be allowable without influence on the thermal behavior of the system.

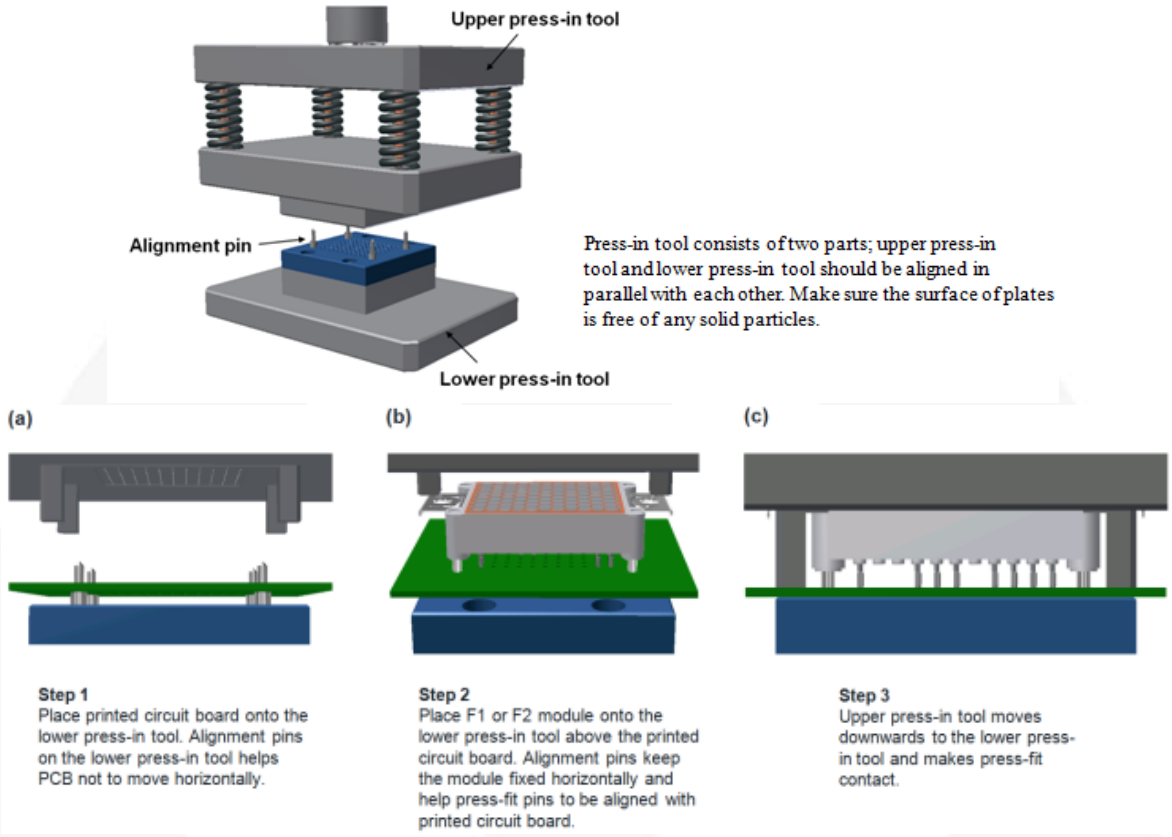
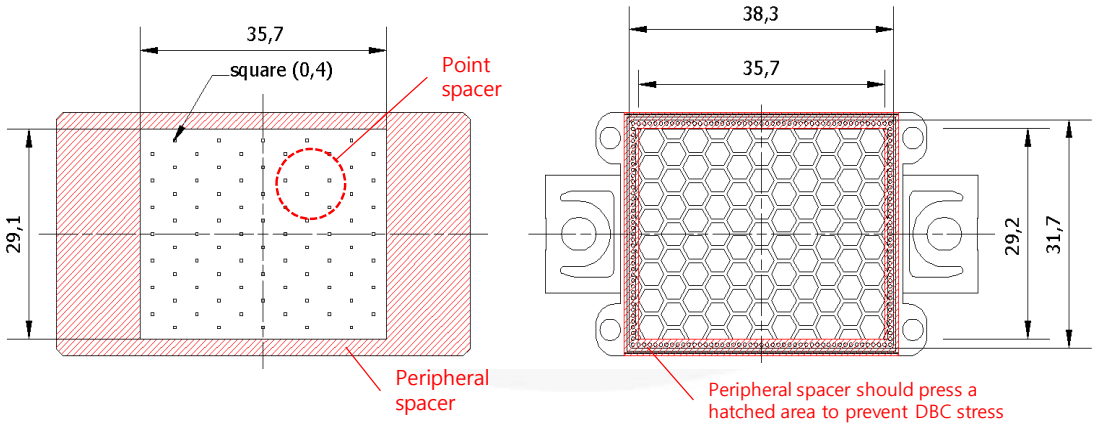


Figure 9. Sequence of Press-in Process (with PCM Spacer)

Figure 10 shows a detailed description of the PCM spacer as an example. Customers can request 2D or 3D CAD drawings of the jig. Please contact your local Fairchild sales manager.



-Peripheral spacer and point spacer prevent from PCM layer damage during press-in.
-Point spacer should be designed to be located between pattern to pattern.
-Peripheral spacer should press the edge of the DBC to prevent DBC stress. Press-in jig should be designed to touch the hatched area on the drawing.
-Peripheral spacer has a role to protect DBC deformation during press-in process.

Figure 10. Detail Image and Description of PCM Spacer (Example for F1 Module)

Handling of PCM Pre-applied Module

Transport and Storage

During transport and storage of the modules extreme thermal and mechanical shock should be avoided. The tray box is designed to prevent direct contact to the PCM layer of the module substrate as shown in the Figure 11. PCM-pre applied modules should be stored in this tray box before its use. Table 4 shows optimum storage conditions. Especially, storage of PCM pre-applied modules above phase change temperature (45°C) is not recommended.

Figure 11. PCM Pre-Applied Module in a Tray Box

Table 4. Recommended Transport and Storage Conditions

Storage Temperature	-25 ~ 40°C
Humidity Condition	10 < RH < 55%
Time	Max. 12 month

Handling

PCM printing layer should be treated as a functional area of the module and be protected from damage or removing when handling or mounting. PCM pre-applied module is delivered in a tray box with a tight cover. It is recommended to open the cover carefully side-by-side to prevent mechanical damage to the PCM layer, as shown in the 0. Also during the assembly process attention is needed not to touch the PCM layer directly. If the PCM layer is contaminated or more than 10% of the entire printed area is damaged, then it is recommended to remove the PCM layer according to the guidance provided below, and to apply thermal grease instead.

Figure 12. Recommended Opening Procedure of Tray Box

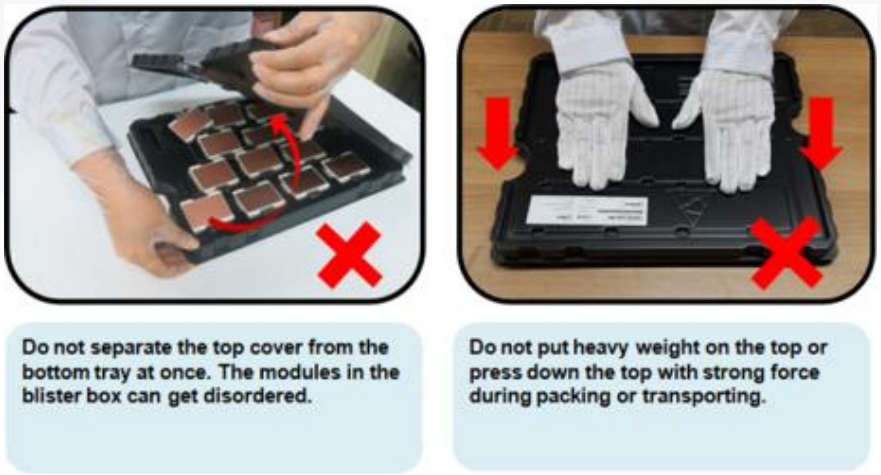


Figure 13. Improper Handling of Tray Box

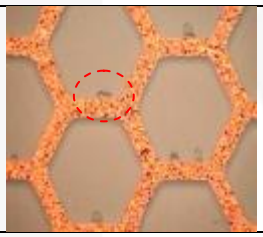
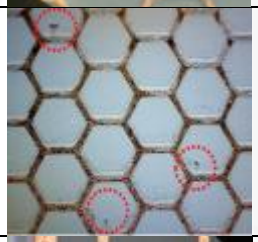
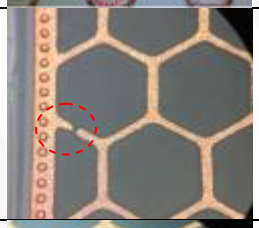
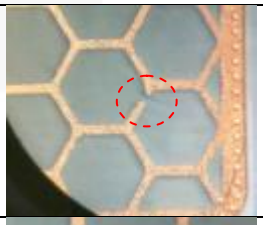
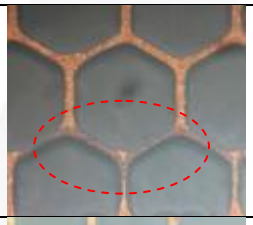
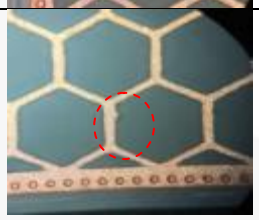
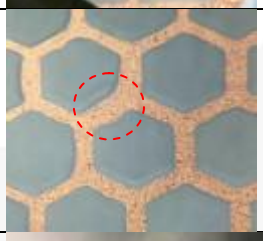
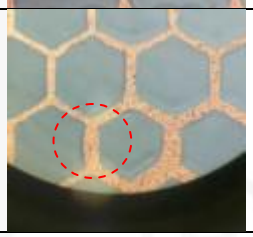
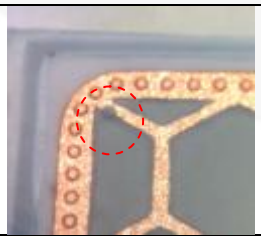
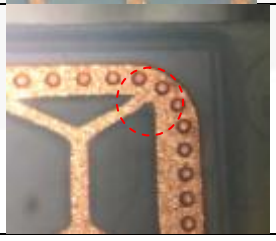
Disassembly, Cleaning and Rework

In case of a failure or if rework is required it may be necessary to disassemble a module. In case of rework before the module was operating, standard PCB / heat sink dismounting process can be applied. If the module was operated and the PCM molten and distributed already, then bond strength between heat sink and the module may be strong and the module cannot be removed from the heatsink easily. In such case it is recommended to use a knife to detach the module or apply some heat (45-60°C) to re-melt PCM to detach the module easily. Use a soft plastic scraper to remove the PCM layer from the module back side and heat sink. For the removal of remaining PCM residues it is recommended to use microfiber cloth.

Printing Layer Inspection

Small deviations of the PCM layer are acceptable and do not influence the thermal performance. Table 5 shows some examples of acceptable printing deviations. However, the surface of the heatsink and the backside of the module, including the PCM layer need to be free of foreign particles to prevent damages to the ceramic.

Table 5. Example of Good Part

1) Uneven PCM Surface by Air Trap			
2) Small Voids on Printing Pattern			
3) Pattern Bridges			
5) Dislocated & Peel Off			
6) Printing on Dimples			

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