Vincotech

Application Note

Application of TIM

Application of thermal interface material onto Vincotech's modules

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1 Abstract

The application of thermal interface material is unavoidable to guarantee a good thermal contact between the power module and the heatsink. The stability over time is the most important characteristic of this material. Especially pre-bended convex module undersides support this requirement. Therefore this application note describes how to apply thermal interface material in a correct and repeatable way. Differences are shown between the application by a roller or by brush, thermal foil and a stencil or silk screen.

2 Introduction

Power modules need to be cooled through a heatsink since passive and active components generate losses which lead into an increase of temperature. To ensure a good thermal contact between the module and the heatsink thermal interface materials are common. These interface materials have a much lower thermal conductivity compared to a DCB or baseplate or to the aluminum or copper heatsink. Therefore the layer of thermal interface material should be as less as possible, but as much as needed. Also the thermal conductivity of the thermal interface material itself has to be taken into account.

3 Methods to apply thermal interface material

Three different methods are common to apply thermal compound to power modules. The most popular technique in many companies is to use a brush or a roller like shown in Figure 1. The second method is to use a spatula or a notched trowel. But the thickness of these pasting methods depends on the operator and too much material as well as too less material results in an increase of junction temperature and reduces the life time as well as the efficiency.
A quite repeatable thickness will be achieved with a stencil or with a silk screen. To guarantee the repeatability Vincotech works with the last mentioned method.

The application by a brush or a roller gives a not defined layer thickness and the application by notched trowel gives a defined thickness of grease but is not well structured.

Figure 1: Brush, roller, notched trowel and can of thermal compound

It is nearly impossible to apply the same amount of thermal grease to each module. Grease is also applied where it's not needed like to the mounting holes. These methods result in a not optimum layer thickness and could cause an increase of temperature.

4 Repeatable application

Two different procedures are known to apply thermal interface material in an accurate way. On the one hand application by stencils and on the other hand application by silk screens. Both techniques are common to apply material in a repeatable way. Differences of using a silk screen or a stencil can be seen which are depicted and described in the following section:

4.1 Application of thermal foil

To make this topic round also thermal foils should be mentioned. Different types of thermal foils are available on the market. Thermal foils that are solid are absolute unusable for example because these can not fill the gaps between the module and the heatsink. Much better are thermal foils with a thin aluminum layer in the middle and coated thermal compound on both sides like depicted in the following figure.

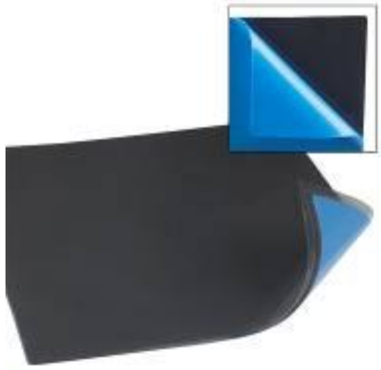

Figure 2: Thermal foil

The coating changes its aggregate state between 50 °C and 60 °C, turning soft. These materials are easy to apply. To apply these foils the liner has to be removed and the foil can then be applied to the module or to the heatsink.

4.2 Application by silk screens

Silk screen printing is a printing technique that uses a metal mesh to support a components blocking stencil. An attached foil forms open areas of mesh that transfer materials which can be pressed through the mesh onto a substrate. A squeegee is moved across the screen, forcing or pumping the material past the threads of the metal mesh in the open areas.

Figure 3 a and b shows the application of components as an example. The screen is fixed just above the module and the component lies in front of the squeegee. The mesh of the screen is pushed down into contact with the module by the squeegee as it moves across the screen, rolling the material in front of it.

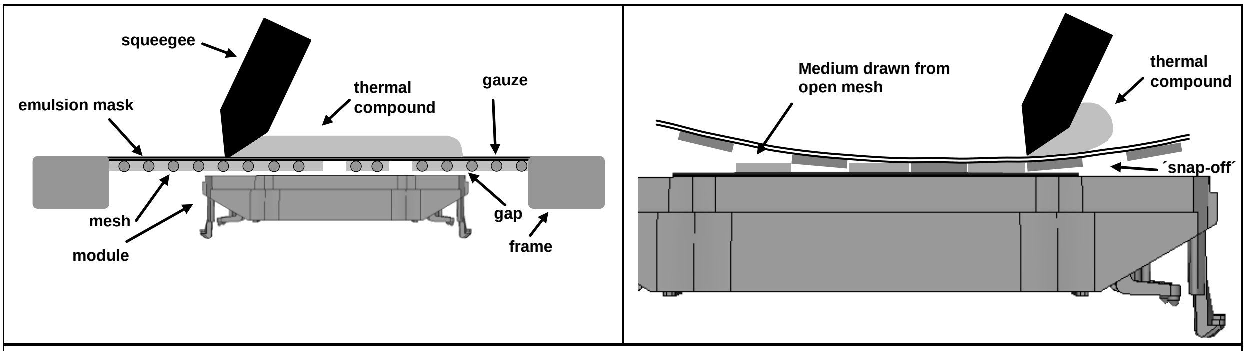

Figure 3a/b: Screen printing process

The squeegee blade presses the material into the open apertures of the screen, and then removes the rest as it passes across the aperture. The screen then peels away from the module behind the squeegee, leaving the material that was previously in the mesh aperture deposited on the module beneath.

Figure 4: Mesh of a silk screen

Silk screens allow applying a very thin layer which can be much thinner compared to stencils. Some thermal material remains in the meshes. Therefore a small variation of component from module to module is given as can be imagined when looking to Figure 4. The effort with these screens occurs in the adjustment above the module as well as in cleaning the screen afterwards. An application by machine with a constant pressure is recommended instead the application by hand.

4.3 Application by stencils

In contrast to screen printing, stencil printing is an ‘on-contact’ process. The stencil is a metal mask with different openings which rests directly in contact with the module. In stencil printing, the module is moved into contact with the stencil before the squeegee starts to move. When the squeegee has done its work, the module and the stencil are then separated vertically, which releases the material from the stencil, producing well-defined edges to the print. An example of a fixture and a stencil for *flow* 2 modules is depicted in Figure 5. Here stencils as well as the adapter that holds the module are exchangeable for supporting also other module families. An application by hand with some putty knife is in the same way possible like an application by machine. Compared to silk screens a minimum thickness of the stencils should be ≥ 80 µm to give some stability to the stencil itself. Therefore the minimum height of applied dots is 80 µm.

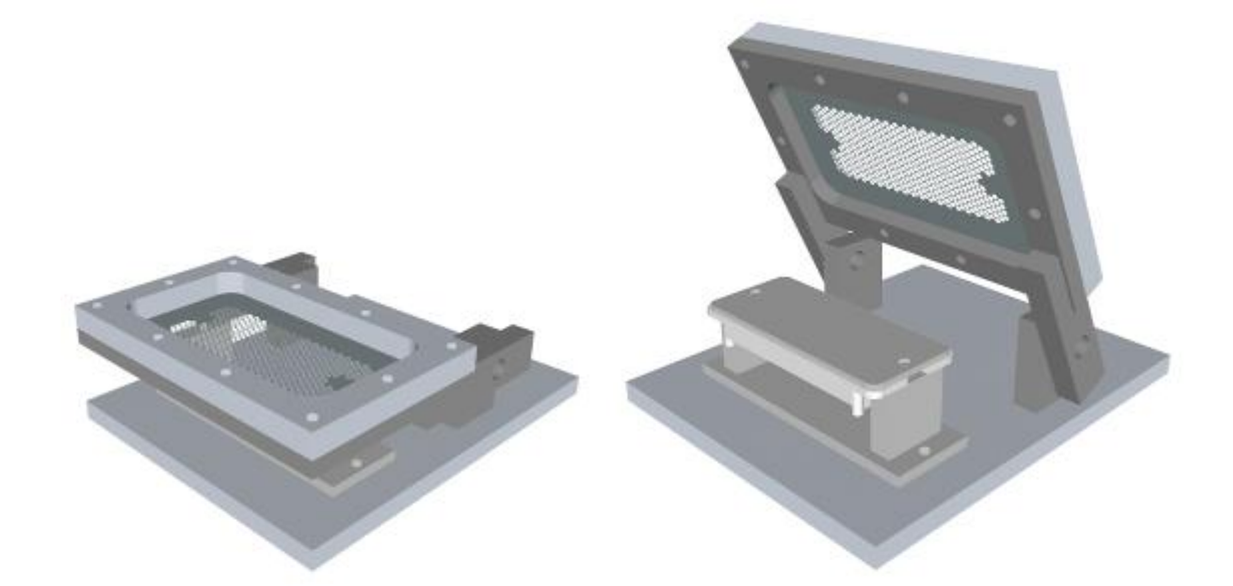

Figure 5: Example of fixture with stencil to apply thermal component

Compared to other stencils Vincotech developed this honey comb shapes to ensure a homogenous spread of grease and an easy cleaning for its silk screens and stencils. A zoom into this structure shows the advantages.

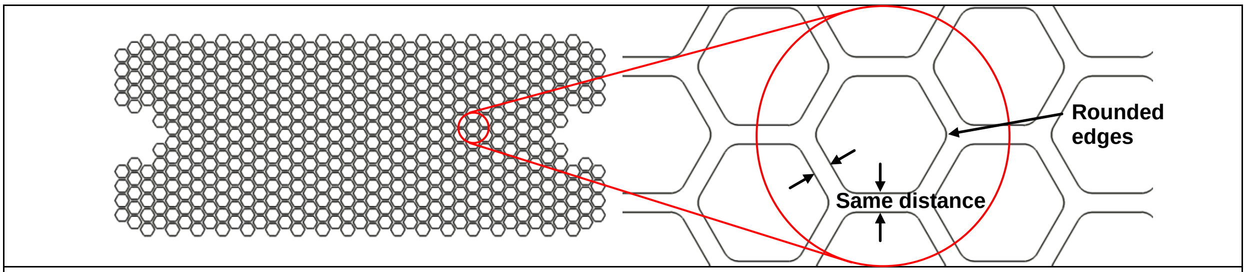

Figure 6: Structure of Vincotech's stencils/screens

The amount of thermal compound can be varied with the thickness of the stainless steel stencils as well as with the thickness of webs. It is recommended to do a laser cutting of the stencil openings instead of a water-jet cut or instead of a chemical etching.

5 Modules with pre-applied PCM

Vincotech offers its modules with a pre-applied layer of phase-change material (PCM). Loctite PSX-Pm phase-change material is used in that case. It has the advantage that it can be applied by screen or stencil printing. It is fluid during the application and dries out over time and temperature. All modules are UL-listed; therefore modules with phase-change material are also UL-approved. They come in a standard blister box with a protective lid.

Modules should be stored in these blister boxes. No aging effect is known; means no expiration date is known for the PCM itself.

The physical and thermal properties of the used phase-change material can be seen below. For more information please refer to the manufacturer's datasheet.

Parameter	Value	Unit
Specific Gravity	2	g/cm²
Thermal Conductivity	3.4	W/m*K
Phase Change Temperature	45	°C
Viscosity above phase change temperature	Thixotropic	
Color	Grey	

Table 1: Physical and thermal properties of the phase-change material

The following figure shows the pattern of the applied phase-change material onto the modules backside in thickness and dimension after the screen printing process.

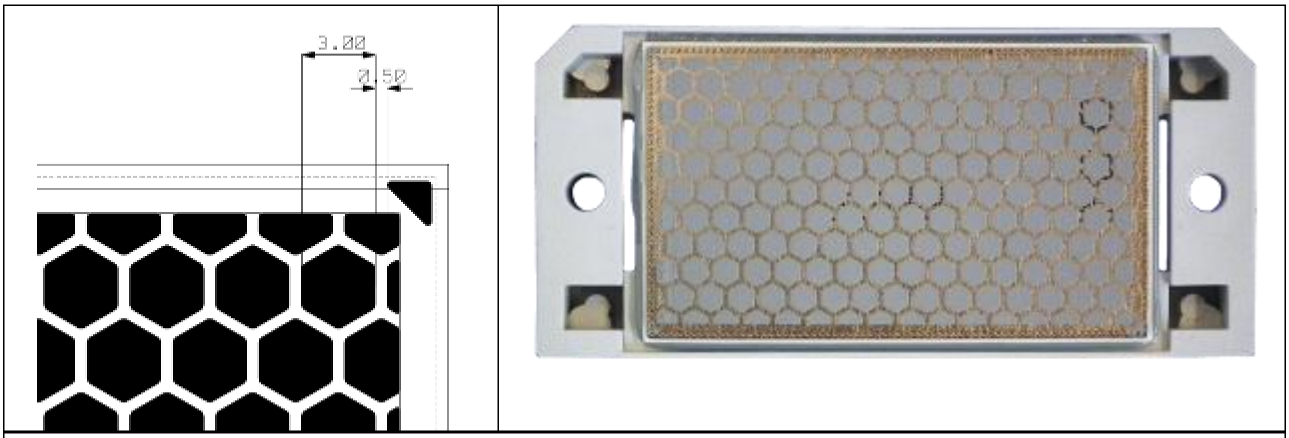

Figure 7: Dimension and pattern after screen-printing

The small triangle at the top right of the printed phase-change pattern is one of four corner markers used to align the silk screening tool to apply thermal interface material. These are also used to align the press-in tool in case of modules with Press-fit pins.

Some black dots are visible between the PCMs dots. These dots are part of the module's part number and the pass stamp and do not influence the materials behaviour.

6 Properties and conditions of heatsink

The properties and conditions of the heatsink are as much important as the properties of the thermal component and the method of application. Hundreds of heatsink suppliers are on the market with the same number of different types. For a good thermal conductivity two properties should be taken into account: The flatness and the roughness.

6.1 Flatness of heatsink

In all mounting and handling instructions a flatness of at least 50 µm within 100 mm length is mentioned. This comes from the past where processes were not well defined and modules were usually based on copper baseplates. In these days where also modules without baseplates with Al_2O_3 and AlN exist it becomes more important to secure a high flatness. Due to a pre-bended DCB, substrates are always convex and the needed amount of grease is reduced to less than 50 µm. It is obviously that non flatness, or a step after the milling process of heatsink would increase the danger of braking substrates as well as increasing the $R_{th(c-h)}$. Figure 8a shows a heatsink for a flow2 module which was milled three times in the area where the module will be placed. Often steps between each milled line occur. The target is to have the module's area milled in one step.

6.2 Roughness of heatsink

The roughness of a heatsink is in interaction with the size of grain particles of the thermal compound. To discuss this more in detail first the roughness of a heatsink is taken into account.
Figure 8a and b shows a milled heatsink and a magnified part of the heatsink.
Different milling areas can be seen in the left figure which is not optimal and can lead to different steps between each milling. The R_{th} can increase as a result of this.

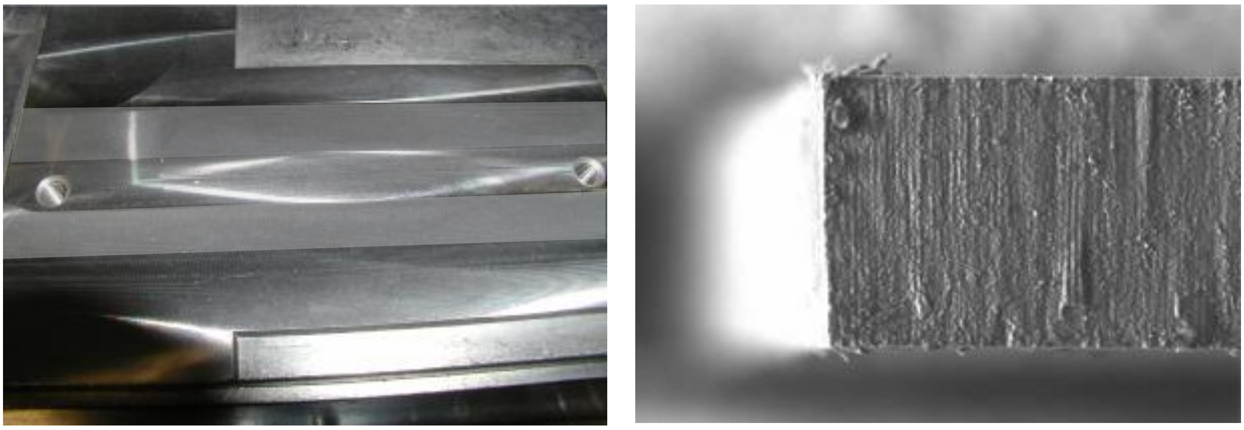

Figure 8a/b: Milled heatsink with grooves / magnification of roughness

Thermal interface materials are used to fill local concavities of the modules backside and the roughness of the heatsink. A typical roughness for a heatsink is equal or less than R_Z = 10 µm. R_Z typically looks only at the five highest and five lowest points in a sampling length and averages peak to valley distances. Additional information about the required properties of a heat sink can be found in the handling instruction of each housing type.

A sketch, Figure 9, shows the roughness of a module's bottom and of a heatsink as an example. Due to the roughness after the milling process hills and valleys occur and a metal to metal contact is only given in a small percentage of the overall area.

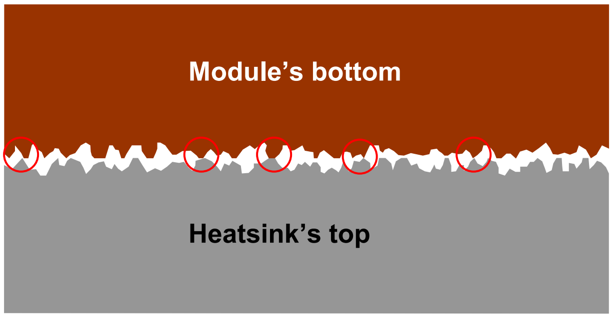

Figure 9: Roughness of baseplate and heatsink

All areas that do no have metal to metal contact have to be filled with thermal interface material. It is obvious that the roughness of both parts is important for a good thermal contact. But also the size of the grains of a thermal compound is very important which is illustrated in the next figure.

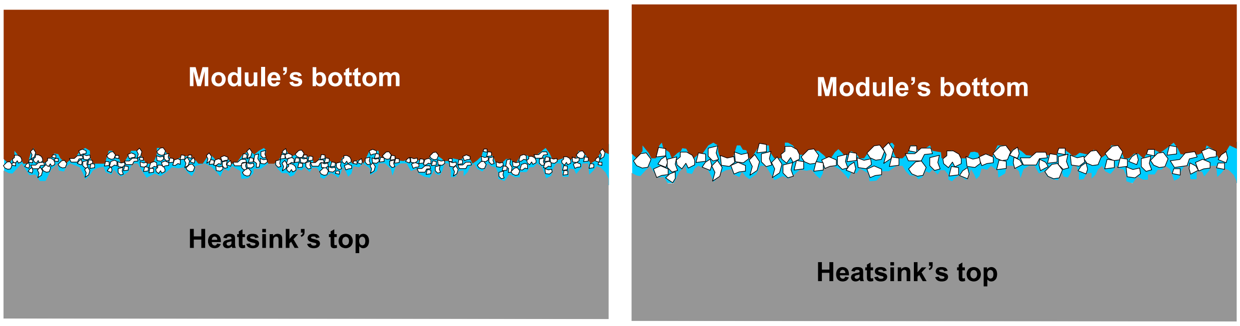

Figure 10a/b: Different grain sizes of thermal interface compound

Figure 10a shows a thermal grease with small grain sizes where the sketch on the right hand shows thermal grease with big grain sizes. Blue areas depict the volatile content of the grease.

A metal to metal contact between the module and the heatsink is given in the left picture where the grain particles work as small distance keepers in the right picture. What this means can be explained with a small resistance circuit.

Through the paralleling of $R_{th(metal)}$ and $R_{th(grease)}$ the thermal conductivity of the thermal compound takes only a part of the total R_{th}. Due to the good thermal conductivity of metal the overall R_{th} is not much influenced by the thermal conductivity of the grease.

7 Conditions of thermal grease

The penetration of grease is most significant in terms of the behavior under pressure. The most important feature of grease is its rigidity or consistency. Grease that is too stiff may not feed into areas requiring lubrication, while grease that is too fluid may leak out. Grease consistency depends on the type and amount of thickener used and the viscosity of its base oil. A grease's consistency is its resistance to deformation by an applied force. The measure of consistency is called penetration.

A penetration of 100 would represent solid grease while one of 450 would be fluid. This is expressed by NLGI numbers.

NLGI Number	ASTM Worked Penetration 0.1 mm at 25°C	Consistency
000	445 - 475	Fluid
00	400 - 430	Semifluid
0	355 - 385	Very soft
1	310 - 340	Soft
2	265 - 295	Common grease
3	220 - 250	Semihard
4	175 - 205	Hard
5	130 - 160	Very hard
6	85 - 115	Solid

Table 2: NLGI numbers

Good experiences with thermal greases were achieved with NLGI number 1 and 2.

8 The right amount; the right shape

To ensure a proper assembly of the module to the heatsink the handling instruction of the affected module should be red carefully. Often the mounting is recommended to be done in two steps.

The next figures show a module mounted on a heatsink where the grease was applied by stencil printing and a picture where the module is in unmounted condition.

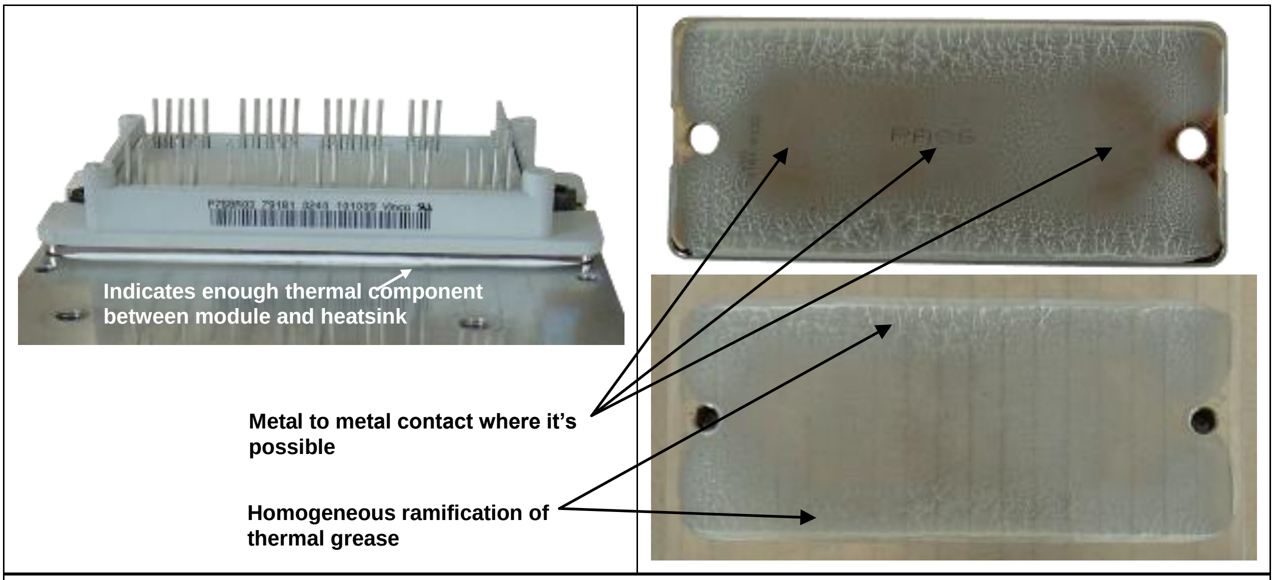

Figure 11: Module in mounted condition and heatsink and module in unmounted condition

A good indicator for enough thermal compound between the heatsink and the module is a small spare amount of grease that is squeezed out after the mounting process. Dependent on the viscosity and penetration of the material it can take several minutes before the grease is squeezed out. This time have to be evaluated with each kind of tested grease. An easy method for evaluation is mounting the module to a glass or acryl glass block. Tests have been shown that the recommended time is approx. 1 hour. After removing the module from the heatsink a structure like shown in Figure 11 illustrates a good thermal contact. The mounting holes in the module and the thread in the heatsink are not daubed with grease. Three areas obviously have a metal to metal contact and the other areas are filled with grease. A ramification of grease indicates no air bubbles below the module.

9 Removing and cleaning

It can be necessary to remove the module from the heatsink in case of rework or a failure. To remove the module from the heatsink it is recommended to unscrew the tighten screws and to lift the module with a knife starting from one edge. Isopropanol or other alcohol with similar properties and a non-woven microfiber cloth can be used to clean the module and the heatsink.

10 Conclusion

Module manufacturer are experienced with developing and building power modules. Therefore thermal conductivities and mechanical features are well known. But also the thermal compound plays an important role for the R_{th} of the complete system. Vincotech presented an easy and reliable process to apply thermal grease with a constant layer thickness. This can be achieved by silk screens and stencils. A honey comb structure prevents air bubbles and offers a uniform flow of grease. A well defined and thin layer is the key for a metal to metal contact from the beginning and can increase also the life-time when it’s used in the right way. Vincotech offers modules with pre-applied thermal grease or phase-change material as an additional service. The process is qualified for all its power modules based on silk screens to achieve thin layers.