Vincotech

Advantages of pre-applied Thermal Interface Material for power modules

Mirko Haardt, Field Application Engineer, Vincotech

There are various interconnection options for all standard power modules—solder or press-fit pins, a selection of pre-applied thermal interface materials, and much more. The latter option, the thermal interface material or TIM for short, is rather important as it can have a—pardon the pun—thermal impact on the module's thermal behavior since it has a huge influence on the heat transfer from the power module to the heat sink.

Conducting a great deal of research in this area, Vincotech tries to find even better ways to meet customers' needs. Recent insights have prompted us to add two new options to our range, silicone-free thermal grease and a high performance TIM.

Power modules convert electrical power from DC to DC, DC to AC, or AC to DC. This is inevitably a loss operation. In every conversion, some electrical energy turns into thermal energy, a little of which lost even in cases where efficiency approaches 100 %. Usually this loss amounts to around 1 % to 8 % of overall losses. This heat has to be dissipated to protect the device's electronic components against thermal damage, which is done by bonding power semiconductors to heat sinks.

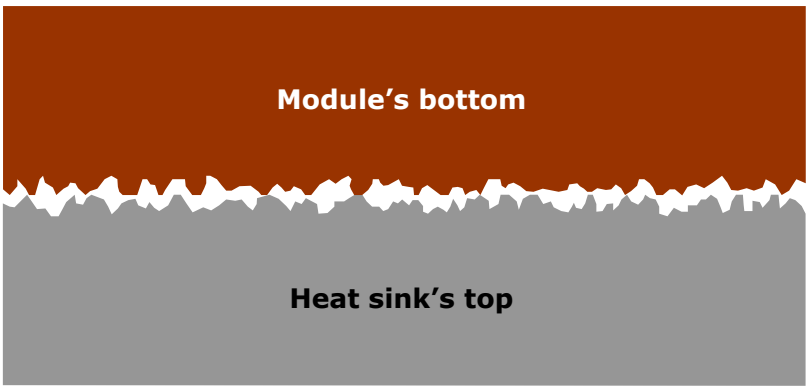

Figure 1: A power module's base connected to a heat sink

The best way to join the two is to apply thermal interface material (TIM) to the junction. It fills cavities on the power module and levels out any unevenness on the heat sink. The TIM complicates things by adding another layer to the thermal model. However, components' surfaces are never perfectly smooth and level, so TIMs are a necessary evil. They offer a proven way of achieving a proper bond between the top of the heat sink and the bottom of the power module.

Thermal grease basically consists of two components; a carrier material and a filling material which is mainly responsible for the thermal conductivity. There are several TIM parameters

having impact on the heat transfer through this thermal layer. The quality of the conductivity is highly dependent e.g. on the size, shape and distribution of the filling material. As an example, Figure 2 shows two TIMs loaded with different grain sizes. The smaller grains are able to fill also small surface irregularities to reduce the contact resistance and the fill factor is even higher which improves the R_{th} of the TIM layer.

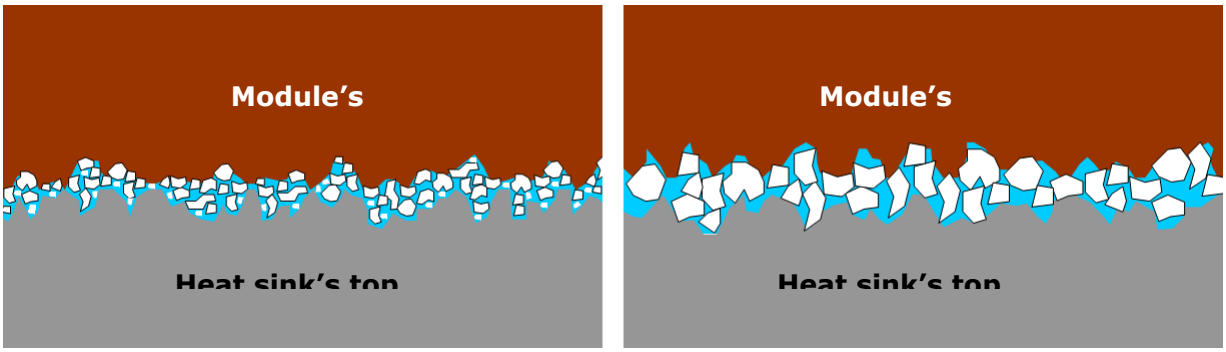

Figure 2: Comparison of two TIMs with different grain sizes

It is no secret that applications are getting more sophisticated. Power assemblies and thermal grease must evolve and improve to meet the demand for smaller footprints, greater power and requirements in special application fields. E.g. silicone-based TIM is forbidden in many automotive environments. Several manufacturers heeded the call. Vincotech tested their products and is now able to offer a selection of pre-applied thermal greases to meet these demands.

As its name would suggest, the greatest benefit of pre-applied TIM is that you do not have to apply the grease. Vincotech does this for you. The advantages are twofold: For one, this saves time and resources by leaving you with one station fewer on the production line. For the other, the TIM's layer thickness and quality never vary. Even now, the standard TIM is often applied by hand with a roller, brush or putty knife. But no one is perfect. Even the most conscientious worker will have an inattentive moment or an off day. The screen-printing process, in contrast, always applies a uniform layer of thermal grease to assure the highest quality in every pass. All TIMs described below are screen-printed.

Standard thermal grease

Vincotech pre-applies Wacker® Silicone Paste P 12, a standard TIM widely used in industry applications. It comes highly recommended as a stand-in for Phase-change material, the details of which are described below. Some housings such as standard MiniSKiiP® power modules are incompatible with Phase-change Material due to too thin or too brittle substrate materials. So this silicone paste is a good substitute that was qualified years ago and has proven its merits in countless applications.

Property	Value
Density at 25 °C	2.1 g/cm³
Dielectric strength	10 kV/mm
Thermal conductivity	0.81 W/m K
Color	White

Table 1: Standard TIM parameters

High Performance Thermal Paste

The latest member in Vincotech's TIM family is the high performance thermal paste TC-6000HP which was just released; it is a silicone compound for exclusive use on MiniSKiiP® power modules. The high performance thermal paste is a standard thermal grease but with optimized filling material. The R_{th} is reduced more than 30 % compared to standard TIM pre-applied on MiniSKiiP® power modules. This consequently results in a higher power density per device.

Property	Value
Density at 25 °C	4.2 g/cm³
Dielectric strength	3 kV/mm
Thermal conductivity	2.5 W/(m K)
Color	Greenish yellow

Table 2: High performance TIM parameters

Silicone-free thermal grease

Silicone is a no-go for many applications. To provide a non-silicone option, VINCOTECH investigated and qualified a Müller Ahlhorn TIM for its MiniSKiiP® housings. Thermigrease® TG20032 is an alternative to Wacker® Silicone Paste P 12.

Property	Value
Density at 25 °C	2.1 g/cm³ to 2.3 g/cm³
Dielectric strength	20 kV/mm
Thermal conductivity	2.5 W/(m K)
Color	Blue

Table 3: Silicone-free TIM parameters

This silicone-free thermal grease has the same behavior and similar thermal conductivity like the standard TIM even though the datasheet value thermal conductivity is much better. Due to the kind of filling material the performance is similar to Vincotech's standard thermal grease. But it is easy to distinguish—it is blue—to rule out any mix-ups when more than one TIM is used for one type of power module on the production line.

Phase-change material

Rolled out by Vincotech years ago, Phase-change material is the alternative to standard thermal grease. Many customers have since opted for Phase-change material, and their numbers are growing. With good reason: Experience has taught our customers and us that this reliable material has some key advantages over standard TIMs.

Property	Value
Density at 25 °C	2 g/cm³
Thermal conductivity	3.4 W/(m K)
Phase-change temp.	45 °C
Viscosity above phase-change temp.	thixotropic
Color	Grey

Table 4: Phase-change Material parameters

Phase-change material's greatest advantages are that it achieves much higher thermal conductivity than most standard TIMs and excellent long-term stability without any pump-out effect. Its stiffness below 45 °C and applicableness in standard solder profiles makes it very easy to use in every production line. The honeycomb pattern's spreads uniformly as soon as the case temperature rises above 45 °C and the module is mounted to a heat sink simultaneously, so that pressure is also applied to the material.

This material is recommended for all *flow* housings with standard Al_2O_3 DCBs and some AlN-based modules.

Several technical papers have described this material's benefits and behavior. The application note “Power Modules with Phase-change Material,” for example, is downloadable on Vincotech's new homepage at https://www.vincotech.com/support-and-documents/technical-library.html.

MiniSKiiP with pre-applied std. TIM

MiniSKiiP with pre-applied silicone-free TIM

flow 1 with pre-applied Phase-change Material

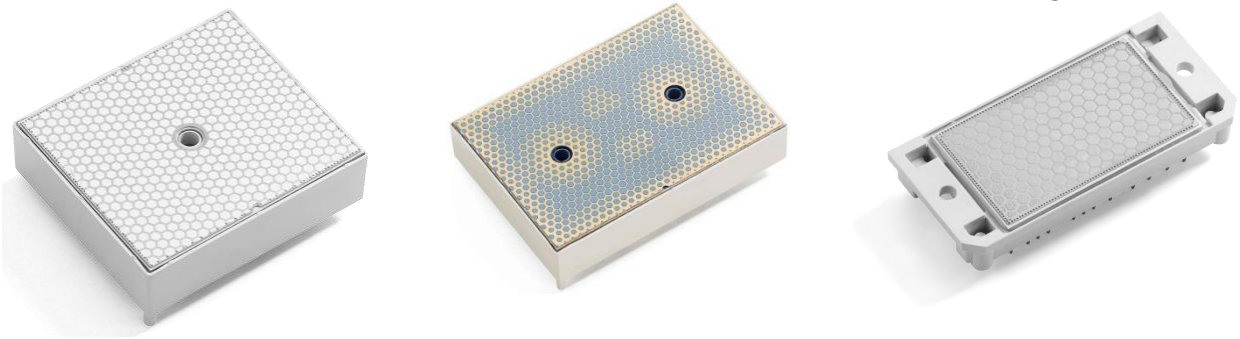

Figure 3: Vincotech power modules with pre-applied TIM

Protection caps

Protective caps are available on request for selected *flow* housings to ensure that the material cannot be touched even when the case temperature is above 45 °C, for example, right after soldering. Besides they are a useful dirt protection during storage or transport as long as the subassembly of pcb and power module is not mounted to the heat sink.

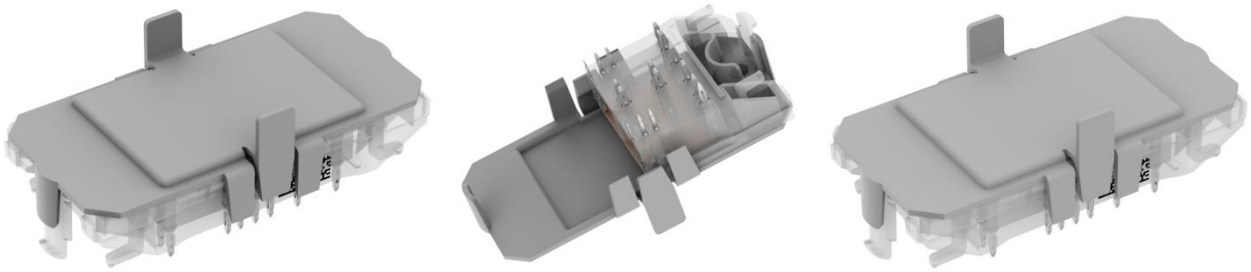

Figure 4: Vincotech TIM protective cap for *flow* modules

MiniSKiiP® housings with pre-applied thermal interface material

Phase-change Material was long an option limited to Vincotech *flow* housings. MiniSKiiP® housings' DCB (0.38 mm, Al_2O_3) was too thin for this material to be a viable alternative, so the standard thermal grease was the only choice of pre-applied TIM available. With the benefit of a recently developed, advanced substrate technology, there are now three TIM options for standard MiniSKiiP® housings and one additional solution for MiniSKiiP® modules with this new substrate technology on offer.

The three options for MiniSKiiP® housings with standard Al_2O_3 DCBs are the tried-and-true Wacker® Silicone Paste P12, Müller Ahlhorn's TG20032 silicone-free paste and the high performance TIM TC-600HC. The fourth option for our MiniSKiiP® line comes with a new alternative to the standard DCBs, an Si3N4 AMB, short for silicon nitride active metal brazing.

This new AMB's remarkable thermal conductivity is four times greater than Al_2O_3 DCBs'. Equally impressive is its mechanical robustness, which enables Vincotech to pre-apply Phase-

change Material for the first time to MiniSKiiP® power modules on an industrial scale. This combination's thermal resistance is 40+ % lower than that of the standard solution with an Al_2O_3 DCB and the usual TIM. What's more, this silicon-based substrate's low expansion rate vastly improves power modules' cycling capability.

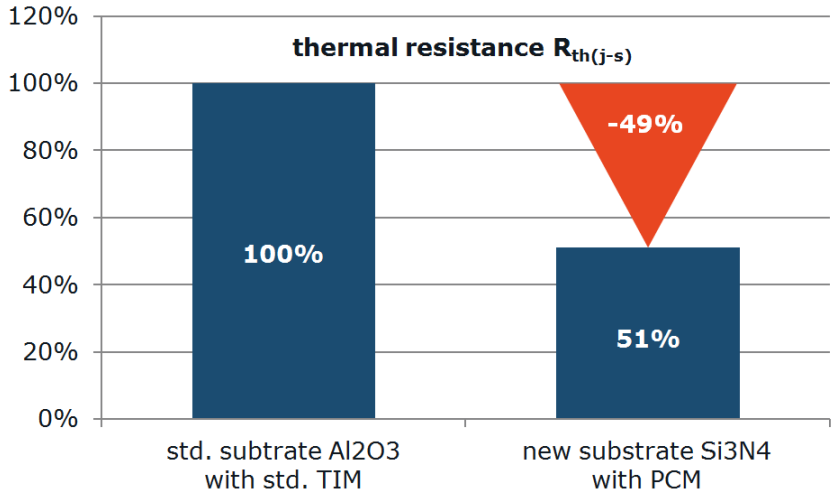

Figure 5: R_{th} comparison between standard substrate with pre-applied standard TIM and new silicon-nitride substrate with Phase-change Material. Both measured on MiniSKiiP 3 sixpack.

Conclusion

If you are seeking a forward-looking partner who provides a range of solutions tailored to your needs, Vincotech is the right choice. The company always endeavors to find reliable new ways to get the job done—not only in terms of housings and chips, but also with options such as pre-applied thermal grease.

Thermal Interface Material	Recommended housing
Standard silicone-based TIM Wacker® Silicone Paste P12	• MiniSKiiP®
Silicone-free TIM Müller Ahlhorn TG20032	• MiniSKiiP®
High performance TIM TC-6000HP	• Exclusively for MiniSKiiP®
Phase-change Material Henkel/Loctite® PSX-Pm	• VINCOTECH *flow* housings with Al2O3 or baseplate • MiniSKiiP® with Si3N4 AMB • others on request

Table 5: TIM overview

References

[1] Technical datasheet for WACKER® SILICONE PASTE P 12, rev. 1.8, 25.06.2015

[2] Technical datasheet for Thermigrease® TG 20032, September 2014

[3] Technical datasheet for Loctite® PSX-Pm, November 2011

[4] Vincotech Application Note, Power Modules with Phase-Change Material, rev. 02, April 2016

[5] Vincotech Application Note, Thermal Interface Material, rev. 01, October 2013

[6] Vince Botyánszki, "MiniSKiiP® with a Si3N4 AMB Substrate", Bodo's Power Systems, October 2016, page 42, 43

[7] Stefan Hopfe, Stefan Häuser, "MiniSKiiP – The Power Density Master for Motor Drives", Bodo's Power Systems, January 2017, page 40 - 43