The new VINcoPress Technology comes with unique capabilities

Patrick Baginski, Sr. Field Application Engineer EMEA

Published in Bodo’s Power System in December 2023

Introduction

Just imagine a power module without baseplate that comes close to – or even outperforms – a standard module with a copper baseplate. By getting rid of the baseplate, you could design smaller and lighter applications than ever, with no degradation of the system solder and no need for multiple DCBs and the electrical connections between them. You’d have more space for semiconductors, less stray inductance, and smaller commutation loops. And with no restrictions in terms of the DCB, isolation materials Al2O3, Si3N4, and even AlN work out of the box and offer superior thermal resistance.

Interested? Then read on, as we compare our new technology to other state of the art technologies in terms of their mechanical, electrical, and thermal performance.

The *flow* S3 housing

Sometimes, you have to start from the scratch and invest in new technologies to develop something unique. This is exactly where we are now. Our R&D team at Vincotech developed a new housing and used new technologies that no one had thought about before. The resulting performance exceeded our expectations. We call it VINcoPress Technology.

Our aim was to develop a low-cost, baseplate-less housing that can be used for string solar inverters of up to 300 kW, especially in three-level topologies. That being said, the housing is not limited to any single topology and can also be used for other applications, such as motor drives, charger stations, and UPS.

Figure 1: The *flow* S3 power module

String inverters need to be light and small. Because they do not require overload capability, they do not necessarily need a baseplate. Moreover, standard technologies have struggled to generate sufficient pressure to the heatsink, in particular for larger DCBs. Overcoming this bottleneck required the development of a new approach. It was this that led to the birth of VINcoPress Technology.

The pressure to the heatsink does not come simply from the mounting screws, the pre-bent baseplate, or the small plastic pin at the center of the housing that gives the DCB its convexity. In case of this new technology, the pressure comes from the "lid." The *flow* S3 module consists of two parts. The first, a plastic frame, holds the DCB. It is the second, the plastic housing shown in Figure 1, that does the magic, in combination with a newly developed silicone gel.

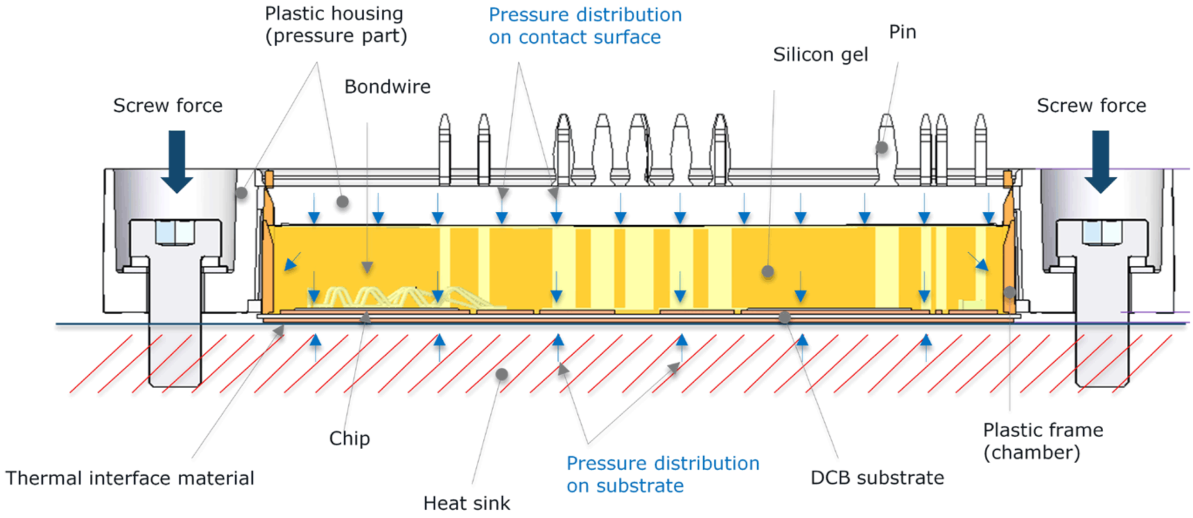

Figure 2: Principle of VINcoPress Technology

Screwing down the module compresses the silicone gel, with the mounting bridges acting as a prestressed clamp. This generates a uniform force inside the plastic frame that presses down the entire module against the heatsink, ensuring a good thermal resistance over time.

The fact that this approach generates a uniform pressure acting on the DCB with no pre-bending opens the door to using fragile substrates such as aluminum nitride, AlN.

The available area on the DCB to place semiconductors, pins, and bond wires is comparable to that of the well-known baseplated *flow* 2 module or the baseplate-less *flow* E3.

Thermal resistance

A fair comparison of the thermal resistance is difficult as the thermal resistance, Rth, depends on the DCB layout and also how much copper is there surrounding the semiconductor. How close to each other are chips? And are they located near to the edges or in the middle of the module?

Keeping in mind that the comparison may be imperfect, let’s take a look at the datasheet values of the thermal resistance of different modules using the same chip:

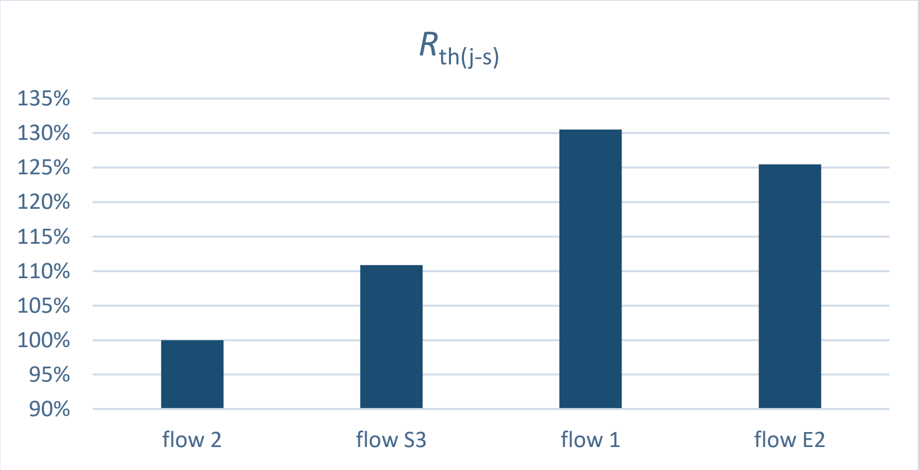

Figure 3: R_{th} comparison of different technologies

The results are striking: This is the first time that the thermal resistance of a DCB module even comes close to that of a power module with a 3 mm copper baseplate. In this example, the thermal resistance of the *flow* S3, which has a 0.38 mm Al2O3 substrate, is 11% than that of a *flow* 2 using the same substrate. Other studies have been even more promising, narrowing the gap to 6%.

At the same time, the *flow* S3 performs far better than the baseplate-less *flow* 1 module, which is based on a 0.63 mm substrate.

The last module in this comparison is the *flow* E2, which is based on a thin, 0.38 mm Al2O3 ceramic base.

Thermal impedance

To cover all thermal aspects, the following chart shows a comparison of the thermal impedance for a *flow* 2 and a *flow* S3 module using the same semiconductor:

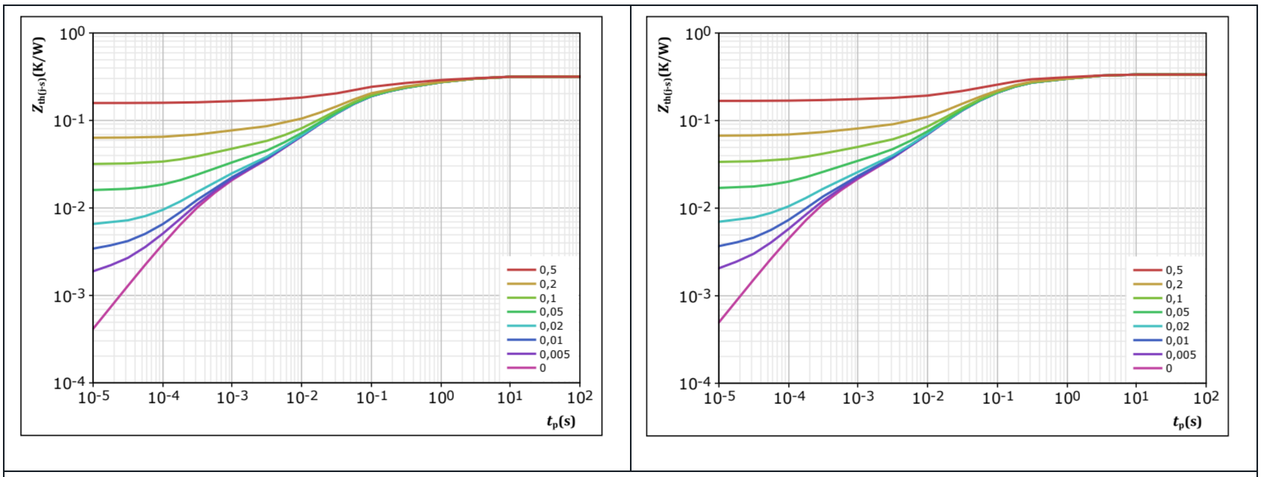

Figure 4: Z_{th} comparison of a *flow* 2 on the left and a *flow* S3 on the right

While the baseplate does improve performance for short pulses as shown in Figure 4, the difference compared to the VINcoPress technology is small.

VINcoPress Technology presses the module to the heatsink with such high pressure that the heatsink itself can serve as a baseplate and absorb some energy. While it may not be quite as good as a baseplate, with the right choice of thermal interface material, it can come close.

So, we’ve seen that the *flow* S3 offers good thermal resistance and excellent thermal impedance. What else does it offer?

Reliability

Reliability is always one of the most important topics to discuss. It is easy to take a poor Rth into account, a high stray inductance, or bad switching performance. But when it comes to lifetime estimations, FIT-rates, failure mechanisms, and warranties, the situation is different.

One factor affecting reliability can be seen from the outside: the absence of nickel plating, which positively impacts power cycling. The *flow* S3 is the first module not to use a nickel-plated DCB, while all other Vincotech DCB modules use nickel plating to prevent growth of dendrites, which like to form in sulfur-contaminated environments. These days, however, dendrite growth has become less of an issue, thanks to improved measures to protect modules against environmental contamination. The second factor might be even more important and affects the reliability by far more than the absence of nickel plating. It is the new advanced solder material that boosts the usage of a power module to the next level. It has the dominant effect in case of power cycling seconds and high temperature forward bias capability.

In the latter case, the failure mechanism is an increase in thermal resistance caused by a void that forms right in the middle of the semiconductor. In the power cycling seconds test, the failure mechanism is either an increase in Rth or bond wire lift-off. In the tests, they compared a nickel-plated DCB to a pure copper DCB.

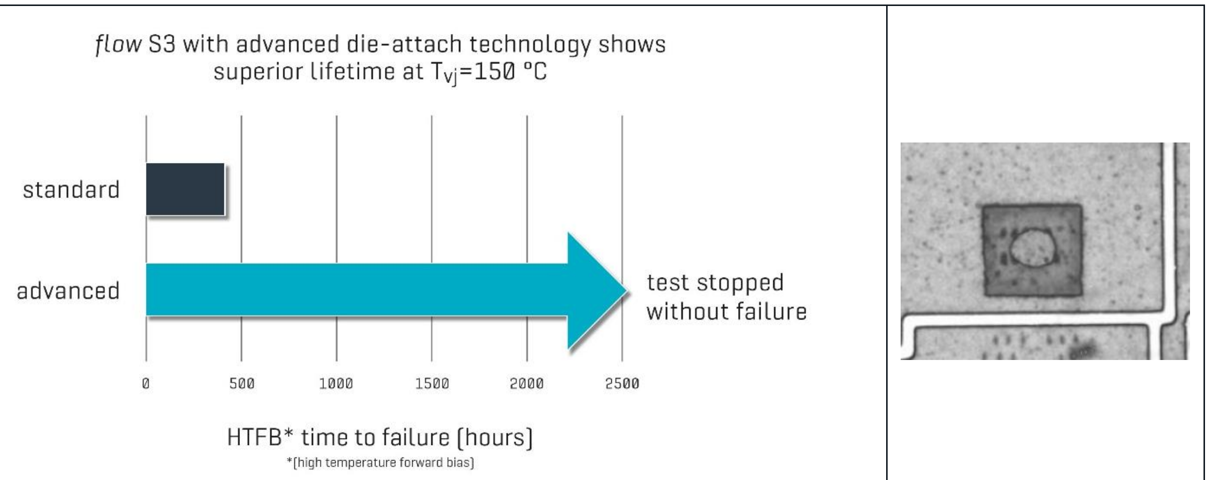

Figure 5: HTFB for the standard and advanced solder alloy and failure mode

As the test condition for the high temperature forward bias test, the researchers imposed a current that raised the temperature of the semiconductor to 150 °C and maintained it at that temperature until the measured Rth increased by 20%. They interrupted the test after 10 times the usual lifetime as they were unable to trigger a failure, indicating that the new solder alloy effectively increases the usable maximum junction temperature. The new solder alloy on a standard nickel-plated DCB increased the lifetime by at least 8 times compared to the standard solder alloy.

Whereas the high temperature forward bias is of interest for solar applications, the power cycling seconds capability is mandatory for drive applications.

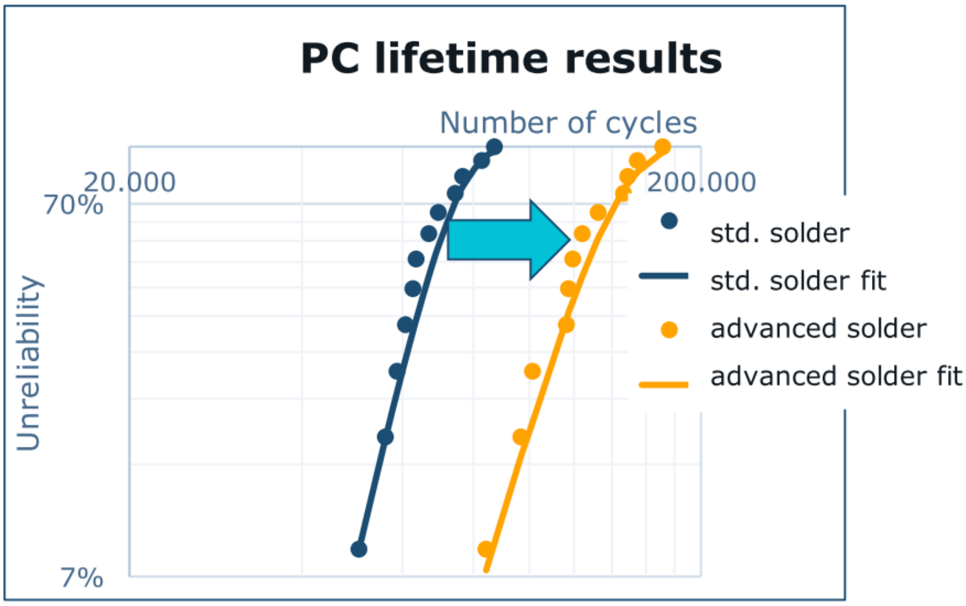

Figure 6: Power cycling capability: old vs. new solder

In this case, the tests were performed at a ΔT of 90 K with a virtual maximum junction temperature of 150 °C and an on time of 2 s. This resulted in an improvement from 72 kcycles to 136 kcycles. Results are based on a nickel-plated DCB. Therefore, an even higher reliability would be expected for non-nickel-plated DCBs.

Using the new advanced solder alloy and driving the component to 175 °C extended the lifetime beyond that of the standard solder alloy at 150 °C.

One aspect related to reliability was not investigated due to the absence of the copper baseplate: the solder degradation of the system solder. This is an important topic as many applications, such as charging stations, are powered on and off several times during the day.

Summary

VINcoPress Technology demonstrated improved thermal resistance compared to standard DCB module technologies and almost closed the gap with copper baseplate modules in terms of thermal impedance.

The complete construction of the *flow* S3 module improves mechanical robustness and makes it possible to use AlN DCBs. The absence of a baseplate did not lead to any system solder delamination.

The new advanced solder alloy allows for higher operation junction temperatures and increases the module's lifetime.

Finally, the new *flow* S3 module comes with unique, previously unknown features, making it a perfect module for a wide range of applications. It is based on the well-known free pin positioning technology that has been used for many years in other Vincotech modules, ceramic capacitors that can be assembled to lower the overvoltage shoot during turn-off, and customized layouts that can be realized as state of the art at Vincotech.