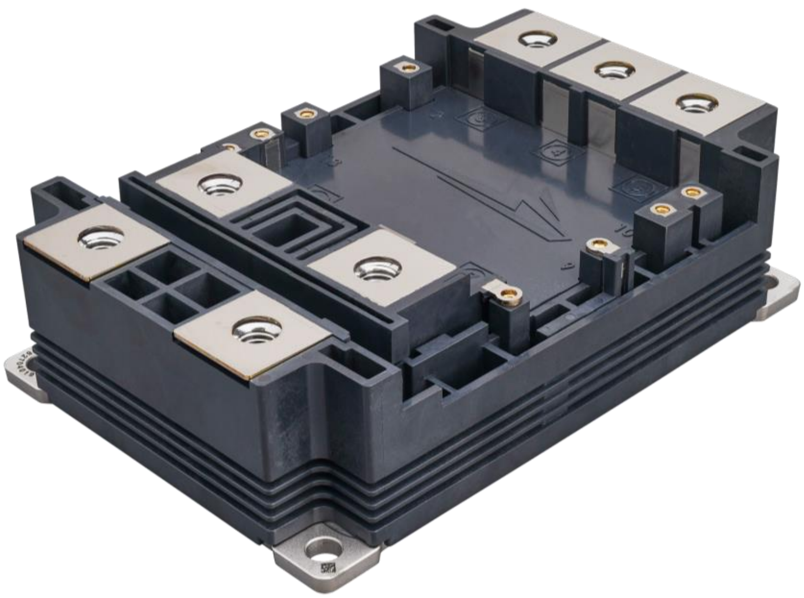
USER GUIDE **PRD-08409**

WOLFSPEED LM3 THERMAL INTERFACE MATERIAL APPLICATION USER GUIDE



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WOLFSPEED LM3 POWER MODULE THERMAL INTERFACE MATERIAL APPLICATION USER GUIDE

To achieve optimal power module thermal performance, it is necessary to mount the module onto a heatsink or cold plate (hereafter termed heat exchanger) to efficiently dissipate the heat generated by the semiconductor devices. This prevents the devices' junction temperatures from exceeding their datasheet maximum rating.

A Thermal Interface Material (TIM) is commonly used to establish proper contact between the module's baseplate and the heat exchanger. However, the thermal grease application and power module mounting to the heat exchanger are crucial for ensuring effective heat transfer between the two-component interface. This application note provides guidance on selecting an appropriate TIM, instructions on how to apply the TIM to the module baseplate, and mounting the power module onto the heat exchanger. By adhering to these guidelines, optimal power module thermal performance can be achieved.

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1. PRODUCT SCOPE

This application note supports all Wolfspeed modules having the LM3 module footprint, including all part numbers with an 'LM' in the last three characters of the part number (e.g., CAB600M33LM3).

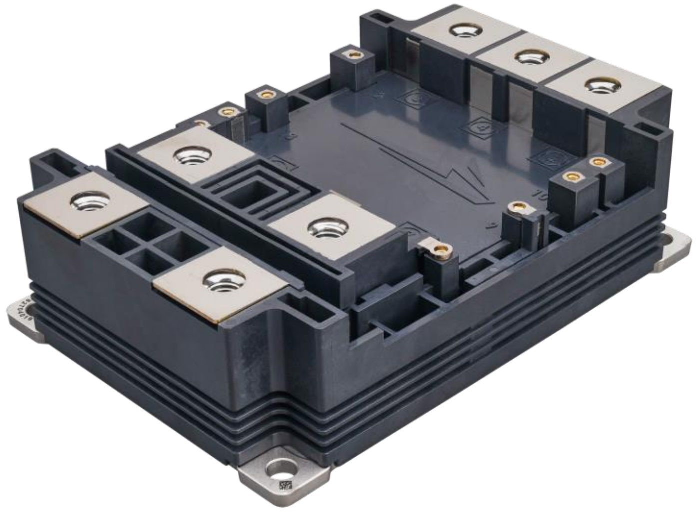

Figure 1. A Wolfspeed LM3 power module

2. INTRODUCTION

One of the most critical power module design considerations is to efficiently move heat generated within the transistors and/or diodes away from their junctions and into the cooling medium. Whether a cold plate or heatsink is used as the heat exchanger, metal-to-metal contact will generally provide the lowest thermal resistance; however, metals will have microscopic voids and irregularities which will prevent perfect joining of the two surfaces. These imperfections will result in small pockets of air being trapped at the thermal interface. The trapped air, in comparison to the metal, is a poor thermal conductor. The purpose of a TIM is to fill the microscopic air gaps between the module mounting surfaces as shown in Figure 2.

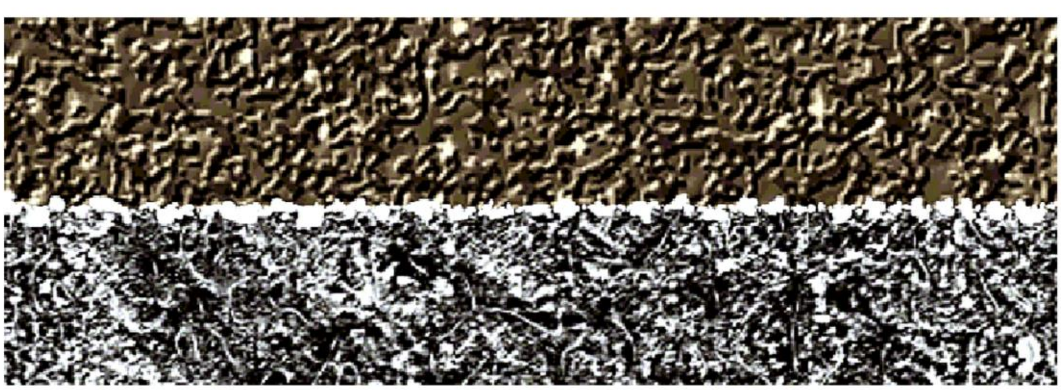

Figure 2. Microscopic voiding between the module baseplate and heat exchanger interface

2.1. TIM SELECTION

There are many different TIM types. Some may be in the form of a pre-cut aluminum sheet, which can be coated with a thermal paste on both sides. Others may be made of either metal alloys or graphite. These TIM types simplify assembly and are less messy, but they add one or more additional thermal resistance layers to the thermal interface. In general, these TIM types are “non-flowable” and cannot completely fill the voids in the metal surfaces. To maximize the module mounting surface-to-heat exchanger contact area, a “flowable” TIM such as thermal paste or grease is recommended. There are many types of TIM available. Thermally-conductive adhesives are also available but are not recommended because they greatly complicate any potential rework.

If the use of a thermal pad is desired, a phase-change material is recommended. These pads can be handled at room temperature but will liquefy at a specified elevated temperature. Some will contain additional material to help fill large voids. Since the material will remain solid until heated, it may be necessary to perform a burn-in or seasoning period and then re-torque all bolts attaching the module to the heat exchanger.

Alternatively, the modules and pads could be assembled onto the heat exchanger, torqued, and put into an oven or thermal chamber until the flow temperature has been reached. (The melting temperature is generally within the range of 45 to 70 °C.) Then, after a dwell period, the assembly could be removed from the oven, allowed to cool, and the bolts could be re-torqued. This method prevents the need for building, tearing down, and re-building a complex assembly. Also, the use of compression washers (e.g., such as Belleville washers) can assist with keeping the module in constant contact with the heat exchanger during thermal cycling. Compression washers are recommended for power module attachment regardless of the TIM used.

Phase-change materials report performance that can meet or exceed the performance of thermal grease but can also be very expensive due to material and tooling costs. Unfortunately, due to their original thickness, they will often result in a bond line thickness that is greater than what could be achieved with a thermal grease. It should also be noted that since phase-change materials will be solid or tacky at room temperature, disassembly can be quite difficult.

2.2. TIM SELECTION AND APPLICATION CONSIDERATIONS

When selecting a TIM, care should be given to make certain that the selection is immune to “pump-out.” Pump-out is caused from thermal cycling that occurs between the two mating surfaces. As the metals expand and contract, they can squeeze the TIM out of the contact area between the module mating surface and heat exchanger, leaving only air pockets which exhibit low thermal conductivity. The TIM must also be resistant to “dry-out” or “bake-out,” which can be caused by thermal cycling, humidity, or extreme temperatures. Select a TIM that has a high thermal conductivity and a low thermal resistance. These figures of merit have units of W/m-K and °C-cm^2/W, respectively.

Within most TIMs are filler particles, which can be made from beryllium oxide, aluminum oxide, zinc oxide, aluminum nitride, boron nitride, silicon dioxide, graphite, copper, silver, diamond, or blends thereof. These particles conduct the heat through the void areas, whereas the grease acts as a suspension. The physical size of these particles can influence the overall bond line. If these particles are too large, they can prevent the desired metal-to-metal contact. A TIM that has particle sizes ≤ 1 µm is recommended. These small particle sizes fit into smaller surface voids, thus increasing the TIM effective thermal conductivity.

Other considerations when choosing a TIM are temperature rating and viscosity. The maximum allowable temperature is often determined by the composition of the suspension oils, grease, or silicones. Organic oils and greases are often unable to withstand the stress of a high-temperature interface. In such cases, a silicon-based TIM should be considered. Because of the large surface area that is to be covered, and the significantly increased risk of substrate cracking, a high-viscosity TIM is not recommended. Low-viscosity grease can compress and spread much easier. To investigate this phenomenon, TIM was applied to an LM3 module baseplate using the recommended stencil and the module was bolted and torqued to a thick sheet of acrylic so the spreading pattern of the TIM could be investigated. Figure 3 shows the difference in spreading between a high- and low-viscosity TIM. Most TIMs are considered thixotropic and require some time in the compressed state before all air escapes and the final bond line thickness is established. In addition, some TIMs will need to be exposed to elevated temperatures and undergo thermal cycling before the maximum thermal conductivity is reached. In some instances, it could take up to 200 hours of operation to obtain peak performance.

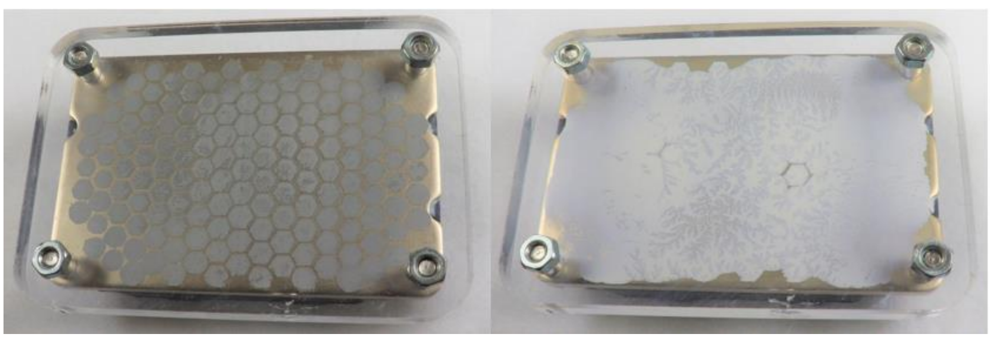

Figure 3. Spreading comparison of (left) high- vs. (right) low-viscosity TIM

A few TIM manufacturers recommend that you “pre-wet” the two contact surfaces. This wetting consists of placing a small amount of TIM onto the module mounting surface and heat exchanger. With a gloved hand or lint-free cloth, the compound is worked into the surfaces at different angles. After that, both surfaces are cleaned, TIM is applied at the desired thickness, and the system is assembled. The purpose of pre-wetting is to help ensure that the particles have been forced into the voids of the metal surfaces. It is worth mentioning that TIM particles cannot be removed from voids once they have been applied by pre-wetting. Further, application of different TIMs for pre-wet and final assembly would skew the thermal interface stack and deviate from the expected performance.

Applying TIM with a rubber or polyurethane roller is acceptable, but the thickness across the entire surface should be verified with a wet film comb (see Figure 4). The target thickness should be 6.0 mil (150 µm). For consistency and repeatability, a stencil or screen-printed TIM application is recommended. While a screen print can allow for uniform TIM thickness, a stencil can provide better control of a variable-volume deposit, which is where the final printed thickness of the TIM varies to accommodate uneven surfaces. An optimum TIM layer thickness will displace all air between the module mounting surface and heat exchanger without preventing the metal-to-metal contact of the two surfaces. Another advantage of a stencil is that cleanup is much easier. A screen often has many small areas where the TIM cannot be completely removed and may therefore “contaminate” future TIM applications.

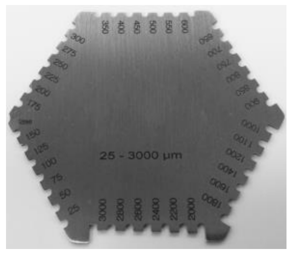

Figure 4. A wet film comb

2.3. STENCIL

Start by selecting a pattern consisting of squares, circles, hexagons or a combination thereof. The combination of stencil thickness, pattern spacing, and aperture size will determine the amount of TIM that is deposited onto the module mounting surface. If the apertures are too small, they will not allow the TIM to release. It is good practice to keep the deposit layer away from the bolt holes. The filler particles within the TIM can prevent the desired metal-to-metal contact at the areas where the module is secured. Those particles may also keep the module from fully seating onto the heat exchanger. Furthermore, if TIM gets into the bolt hole threads, it can influence the applied torque.

A candidate stencil design for the LM3 power module uses hexagons and the apertures are adjusted to allow for a variable-volume deposit (see Figure 5). A `.dxf` file of this design can be provided upon request.

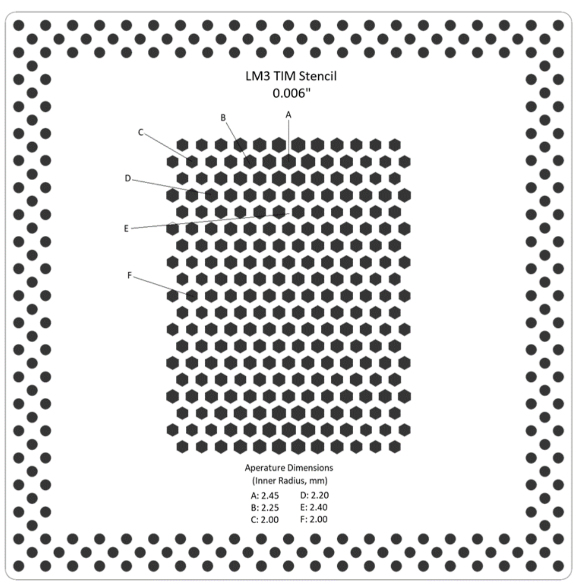

Figure 5. Wolfspeed LM3 stencil

3. TIM APPLICATION PROCEDURE

A fixture should be used to ensure proper alignment of the stencil and the power module (see Figures 6 and 10). The stencil should be able to lift off the module without causing any distortion to the printed pattern. Higher- viscosity TIM may not easily release from the stencil, so it is recommended to secure the module in the fixture so that the module is not lifted when lifting the stencil.

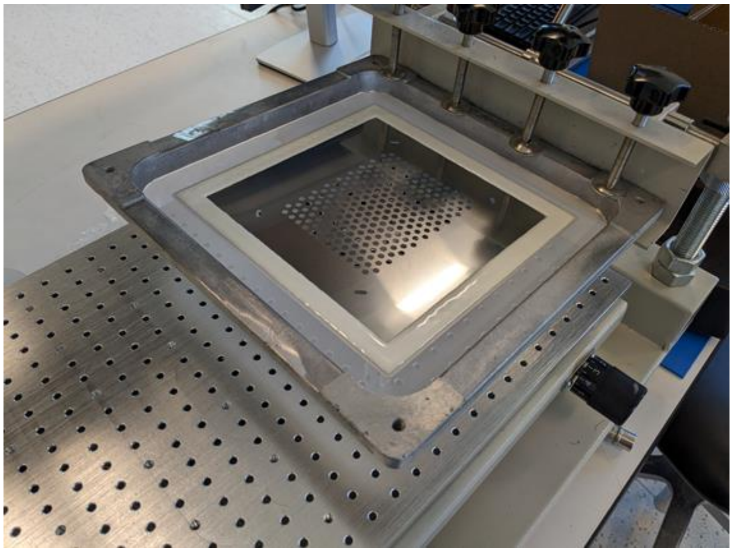

Figure 6. Stencil fixture

When handling or applying TIM, follow all the manufacturer's precautions and guidelines, including personal protective equipment recommendations. To prevent dust or debris from being introduced into the bond line, the TIM must be applied at a clean and ESD-safe workstation. Carefully inspect the stencil and fixture to ensure it is free of any previously applied TIM or dirt. All handling of the power module will need to be performed while observing ESD-safe rules and practices, which includes a high-impedance grounded conductive mat or table and an ESD wrist strap (see Figure 7).

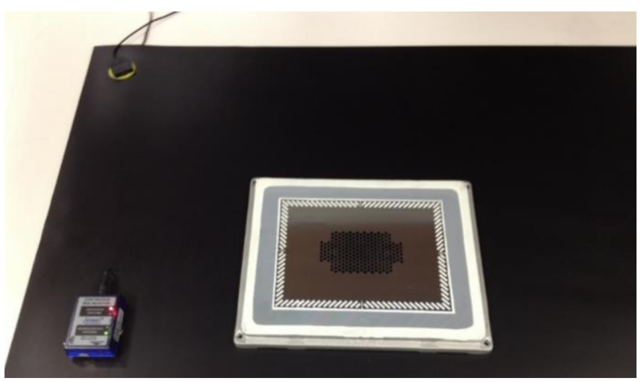

Figure 7. A clean and ESD-safe workstation

1. On the power module, ensure the shorting connectors are on both gate-source auxiliary terminal pairs. Carefully inspect the surfaces of the power module and heat exchanger to

ensure that they are free from contaminants. Prepare these surfaces by cleaning them with isopropyl alcohol and a lint-free towel.

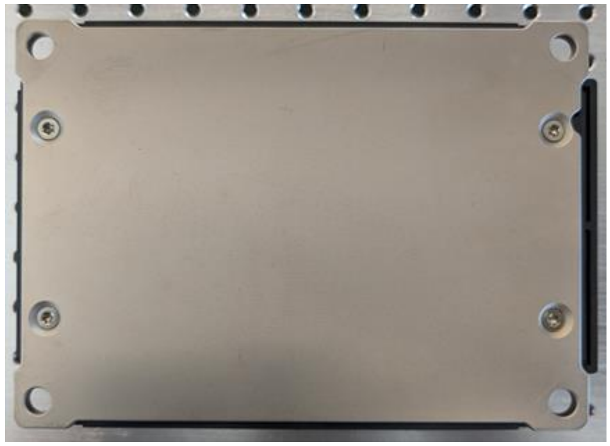

Figure 8. Clean LM3 module

2. Place the module into the fixture and lower the stencil. The stencil must be coplanar with and come into full contact with the module mounting surface. If there are any gaps between the two surfaces, excessive TIM will be deposited. To ensure the desired amount of TIM is deposited, the squeegee or trowel must leave the TIM flush with the stencil surface.

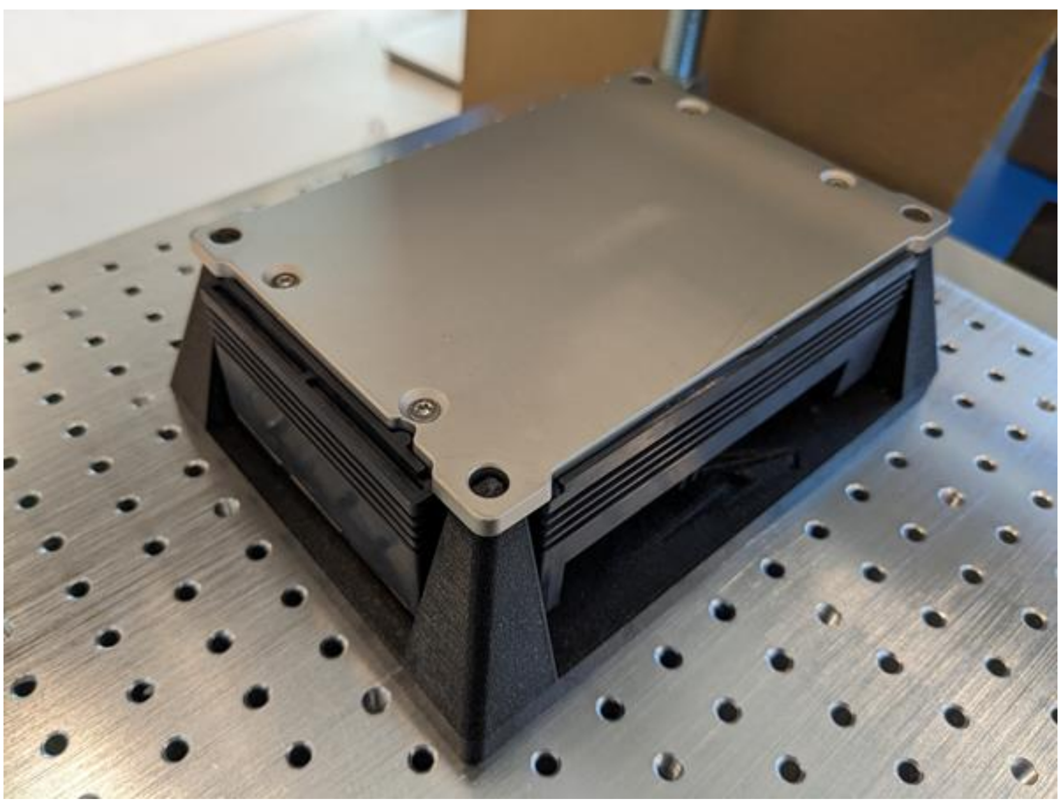

Figure 9. LM3 module in fixture

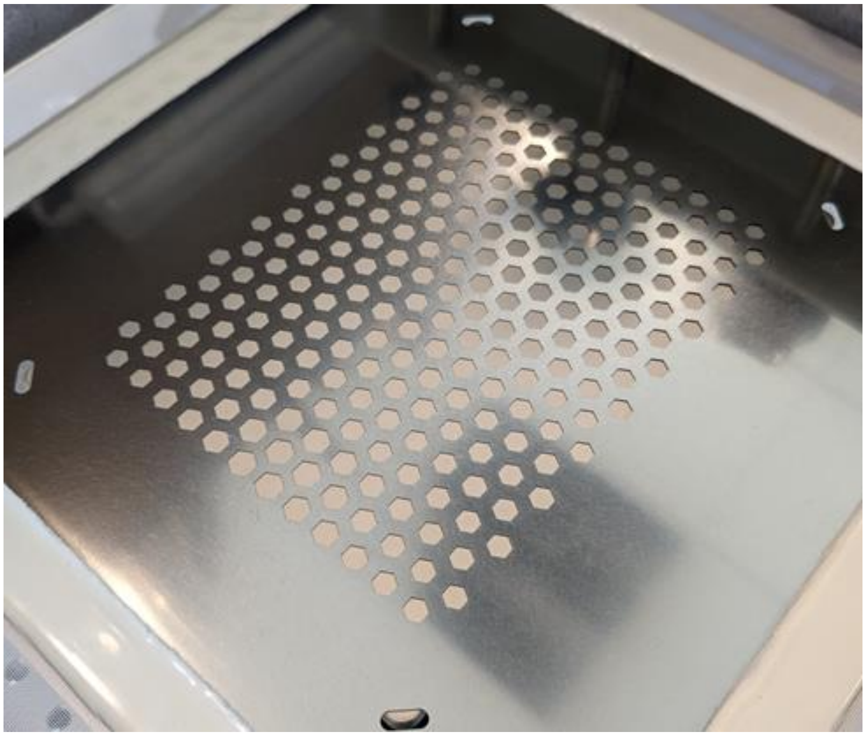

Figure 10. LM3 module in fixture with stencil-to-mounting surface in full contact

If the stencil aperture is too large or the squeegee durometer is too low, cupping—shown in Figure 11—can occur, and the final deposit thickness will be less than the target thickness. If a squeegee is used, the durometer should be approximately 80. If a metal trowel is used, it must make full contact with the patterned area.

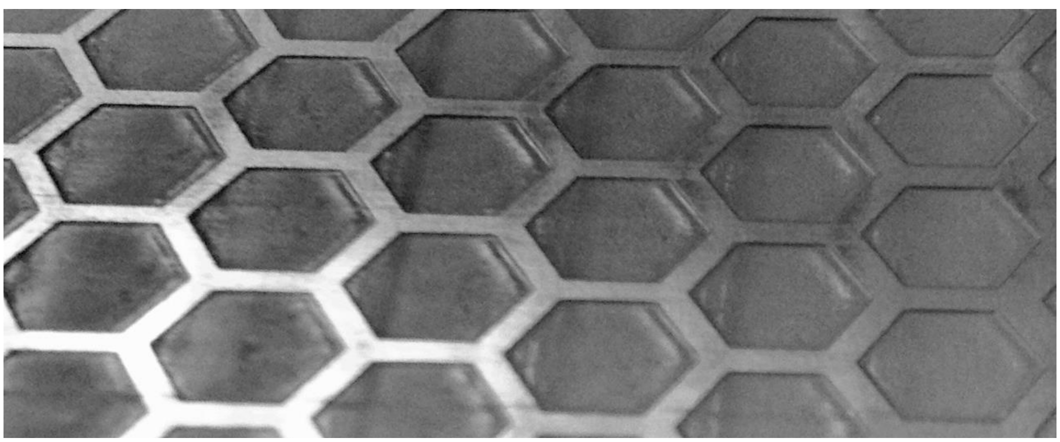

Figure 11. Cupping due to a low durometer squeegee

3. Dispense some TIM onto the stencil at the edge of the pattern. The amount of TIM applied can be adjusted to limit waste. The squeegee should be held at a 45° angle (see Figure 13).

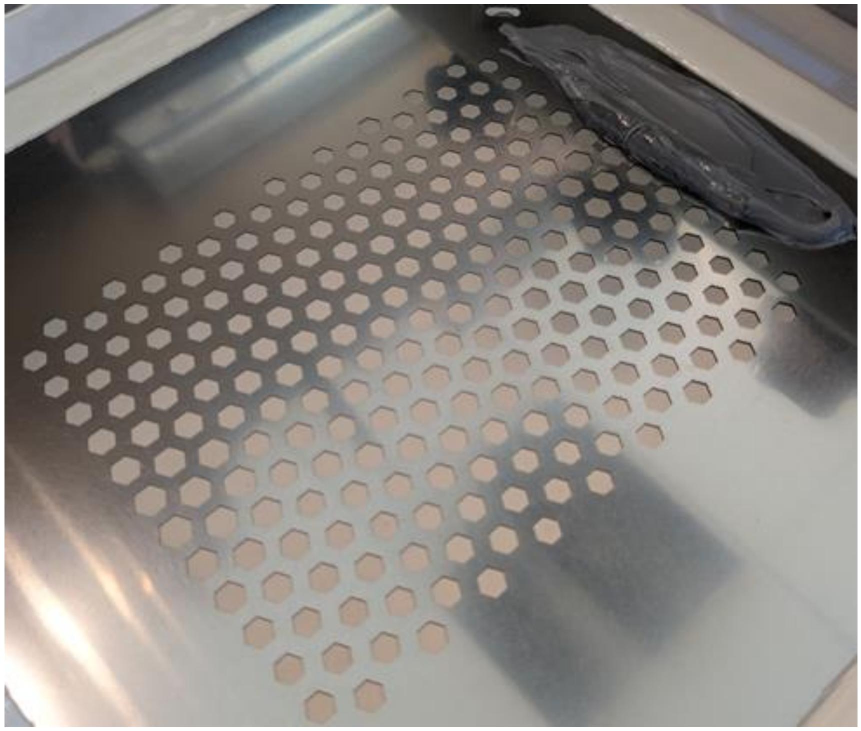

Figure 12. TIM application amount

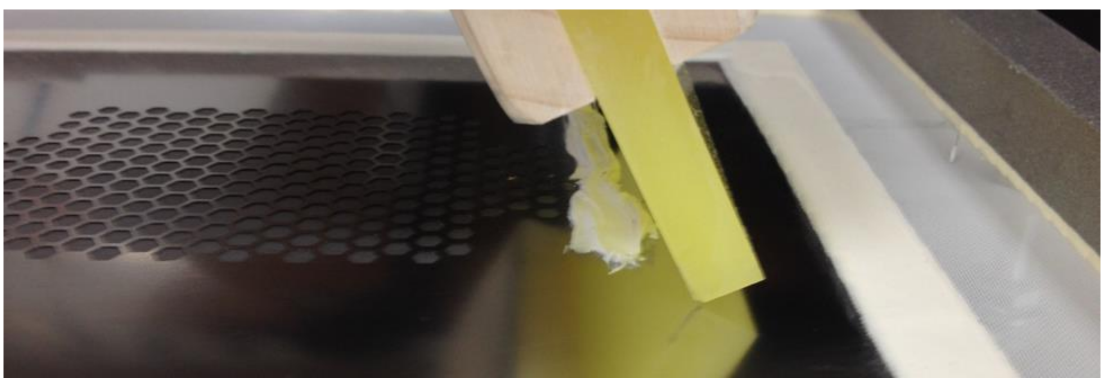

Figure 13. Suggested squeegee application angle

4. Drag the squeegee across the pattern, applying only enough downward force so that the stencil surface is free of TIM after the squeegee passes. Inspect all the apertures to ensure they are completely filled and that there is no cupping. Once verified, remove the module from the fixture and inspect the pattern. There should be no bridges of TIM between the apertures (see Figure 15).

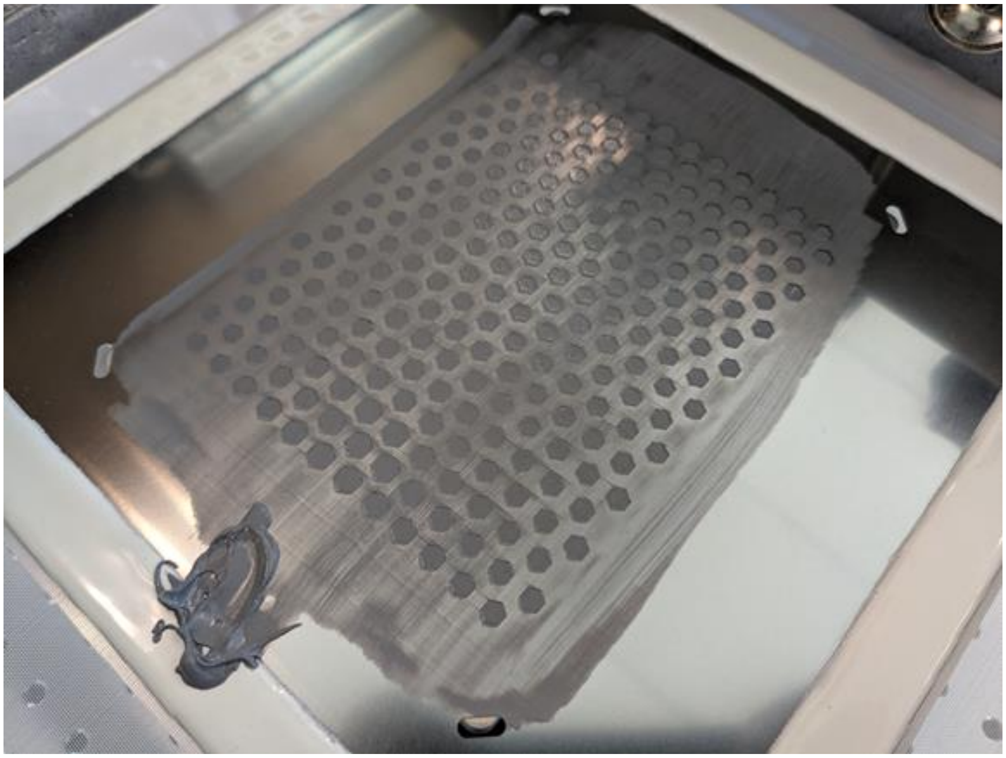

Figure 14. Correct application of TIM to stencil

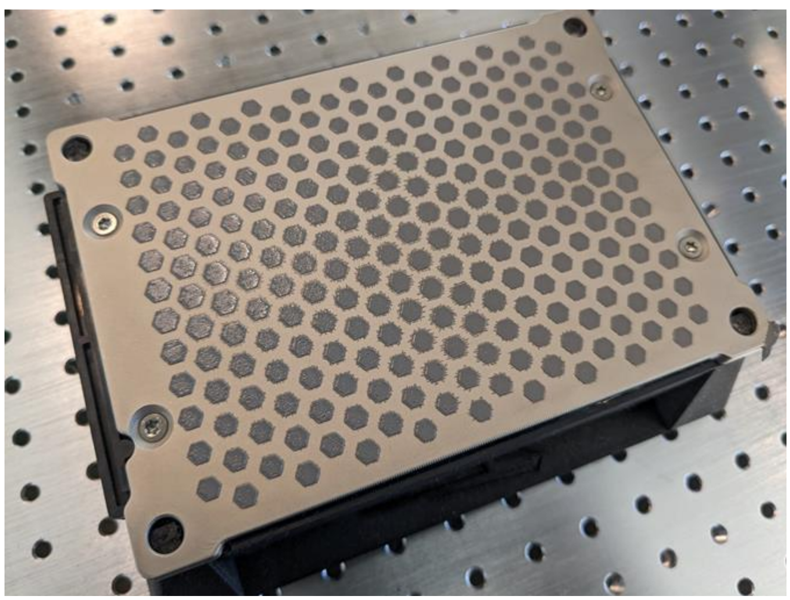

Figure 15. Inspection of stencil-printed TIM

3.1. ASSEMBLY

After applying the TIM layer to the module, carefully align the mounting holes and place the module onto the heat exchanger taking care not to slide the module. If the module is slid excessively, the spreading pattern will become distorted, and the resulting TIM layer thickness will be unknown. If this occurs, remove the module, clean all the surfaces, and repeat the printing process. (TIP: Using a squeegee for TIM removal should be quick and should not scratch the surfaces.)

Install the washers and thread in the M6 bolts until seated finger tight. Following Figure 16 and using a torque wrench, tighten the bolts in the sequence described below until the desired torque is reached. The recommended torque is 4.5 N-m.

1. Torque bolt number: 1 – 2 – 3– 4 to 1/3 final torque (1.5 N-m);
2. Torque bolt number: 3 – 4 – 2 – 1 to 2/3 final torque (3 N-m); and,
3. Torque bolt number: 2 – 1 – 3 – 4 to final torque (4.5 N-m).

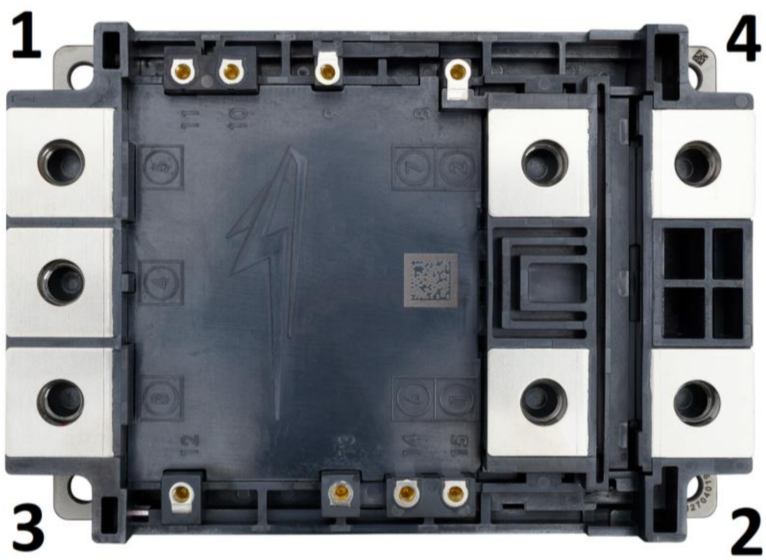

Figure 16. LM3 bolt pattern reference

3.2. VERIFICATION

To verify that the correct amount of TIM has been used, it is highly recommended that the module be removed from the heat exchanger and the TIM layer inspected. If the module is removed immediately after assembly, the TIM layer may not have had time to fully spread and push out the air; therefore, it is recommended that the module be torqued and allowed to rest for at least two hours. In the case of high-viscosity TIM, consult the TIM manufacturer for their recommended rest time.

Extreme care must be taken when the module is removed so the spreading pattern is not disturbed and that the surfaces are not scratched. This can be difficult but using a non-marring tool such as a plastic chisel should help to remove the module in this manner.

As illustrated in Figure 17, only a minimal amount of TIM was pressed out along the edges, which means that an excessive amount was not applied. Closely inspect the two surfaces and ensure there are no bare spots. The optimal layer will have wetted both surfaces, but not be so thick as to prevent metal-to-metal contact. Once the TIM layer interface has been verified, the surfaces can be cleaned, the TIM re-applied, and then the module can be put into the final assembly. If the heat exchanger selection is changed, this verification should be repeated.

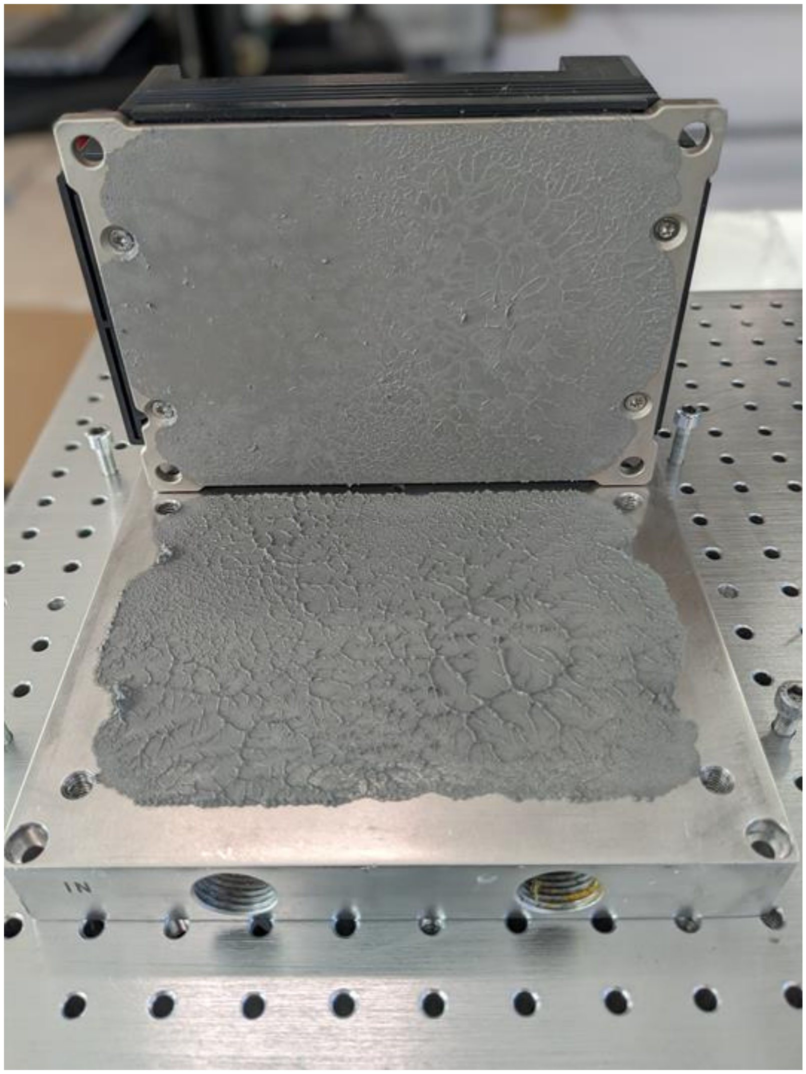

Figure 17. TIM layer inspection

4. REVISION HISTORY

Revision	Date	Notes
1	May 2024	Initial Release