

CPWR-AN42

FM3 Thermal Interface Material Application Note



This document is prepared as an application note to install Cree® evaluation hardware. All parts of this application note are provided in English. If the end user of this reference design is not fluent in this language, it is your responsibility to ensure that the user understands the terms and conditions described in this document, including without limitation the hazards of and safe operating conditions prior to use/implementation.

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1. Introduction

One of the most critical design considerations for a power module to operate at its full potential is the ability to draw heat generated within the transistors and/or diodes away from their junctions and into the cooling medium. Whether a cold plate or heat sink is used, a 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 conductor of heat. The purpose of a thermal interface material (TIM) is to fill in the microscopic air gaps between the module mounting surface and heat exchanger as shown in Figure 1.

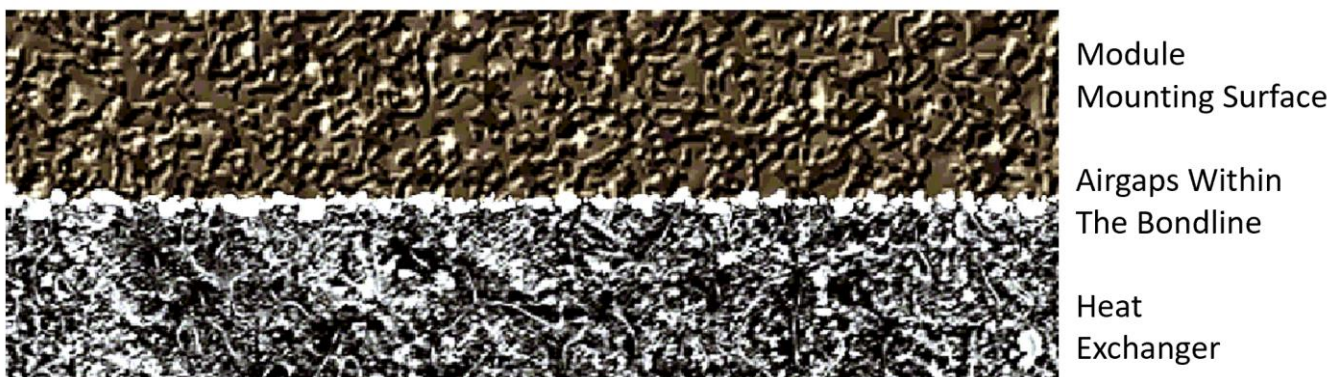


Figure 1 Representation of the Microscopic Voiding Between Adjacent Metal Surfaces

1.1. TIM Selection

There are many different TIM types. Some may be in the form of a pre-cut sheet of aluminum, 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 layers of thermal resistance 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 re-work.

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 an additional material to help fill large voids. Since the material will remain solid until heated, it may be necessary to perform a burn-in 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 Bellville or compression 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 which TIM you use.

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, they can make disassembly quite difficult.

1.2. 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 have 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-cm²/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 a blend thereof. These particles are what 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 $\leq 1 \mu\text{m}$ is recommended. These small particle sizes not only fit into smaller voids, but the compound will require a lesser amount of poorly conducting suspension materials.

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 silicone-based TIM should be considered as an alternative. Because of the large surface area that is to be covered, 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 XM3 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 2 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 TIM 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.

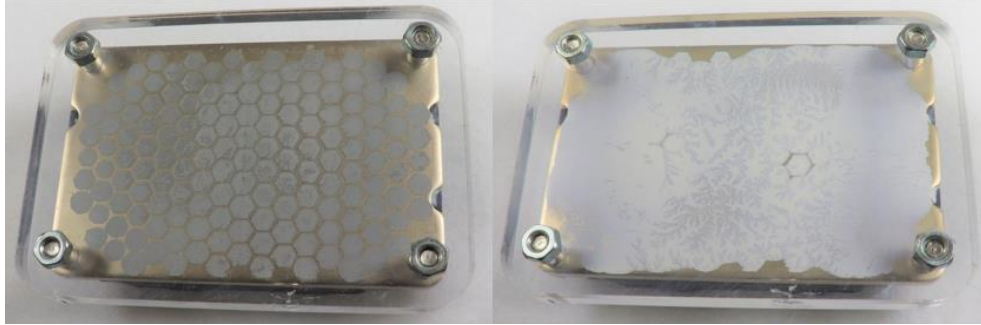


Figure 2 Spreading Comparison of High (left) vs. Low Viscosity (right) TIM

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. If you plan to compare different types of TIM, keep in mind that once these particles are forced into the voids, it will be nearly impossible to remove them all by any cleaning method. This can skew the results of any subsequent thermal tests.

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 3). The target thickness should be 6.0 mil. 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 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.

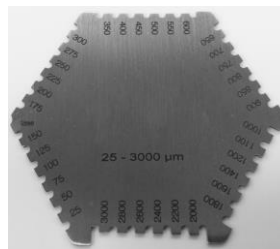


Figure 3 A wet film comb.

1.3. 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.

The Cree stencil for the FM3 power module uses hexagons and the apertures are adjusted to allow for a variable volume deposit (see Figure 4). A .dxf file of this design can be provided upon request.

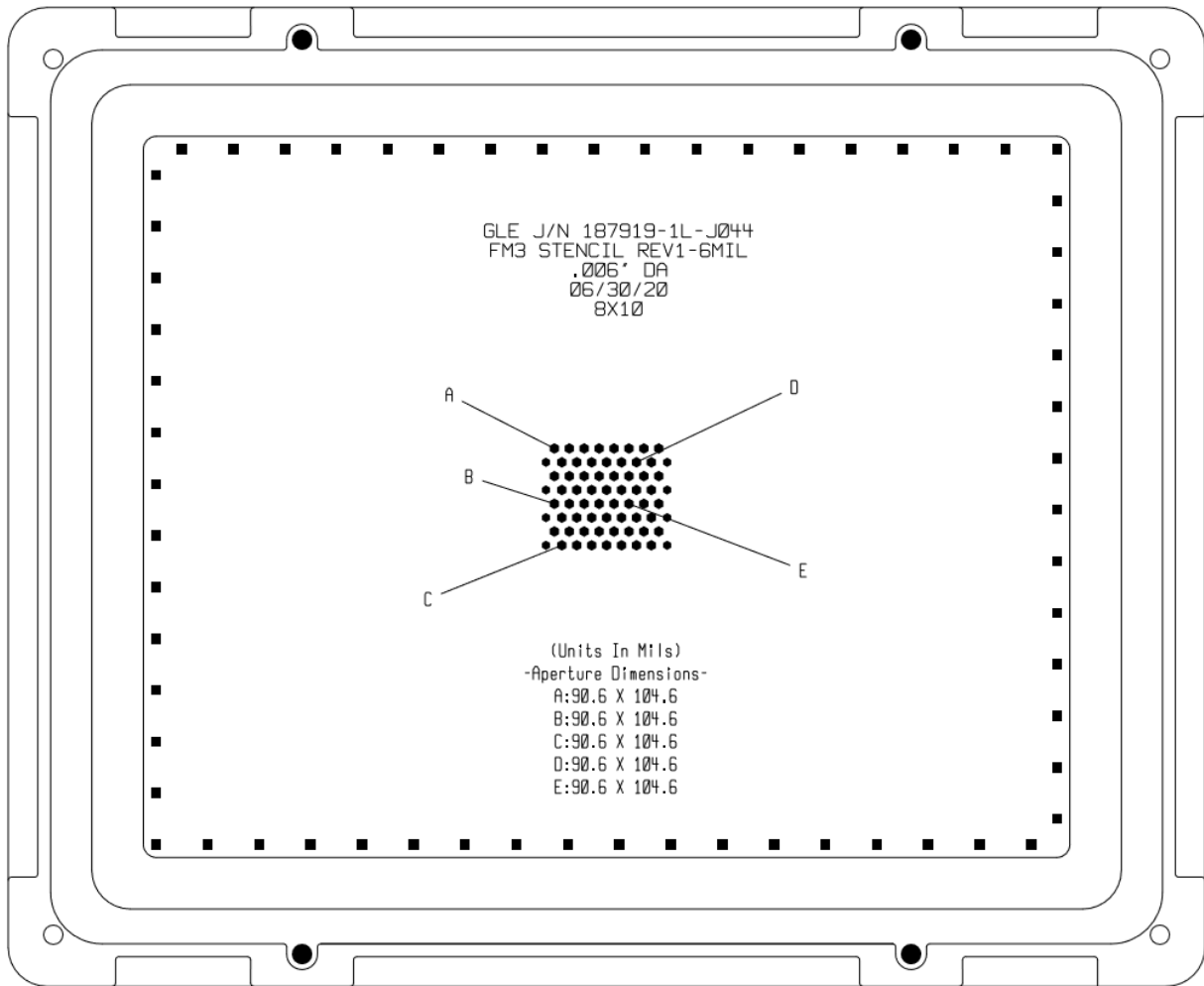


Figure 4 Cree FM3 Stencil

2. TIM Application Procedure

A fixture should be used to ensure proper alignment of the stencil and the power module (see Figures 5 and 9). 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.

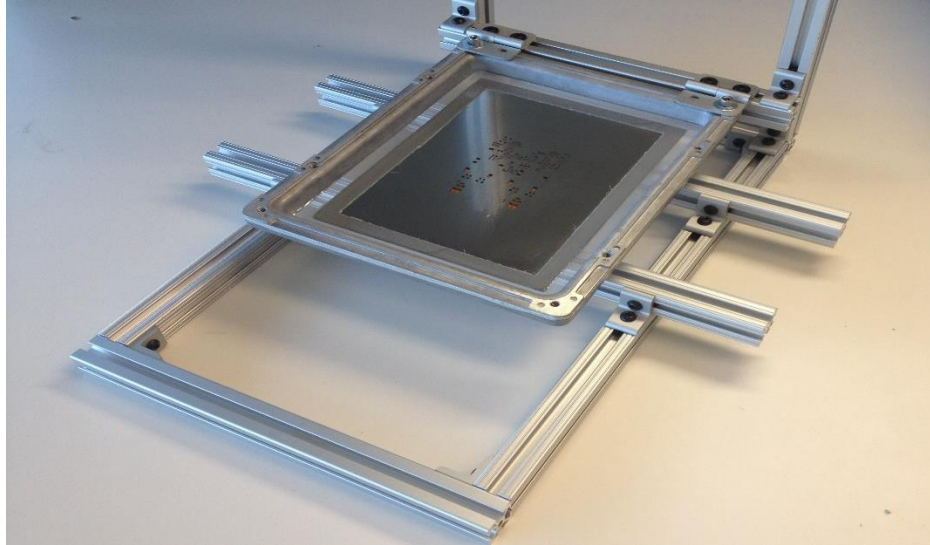


Figure 5 The Stencil Fixture

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 in 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 6).

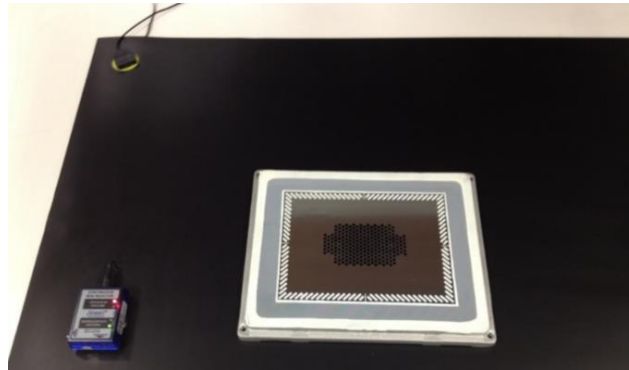


Figure 6 A Clean and ESD-Safe Workstation

1. On the power module, ensure the shorting connector is on both gate-source headers. 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.

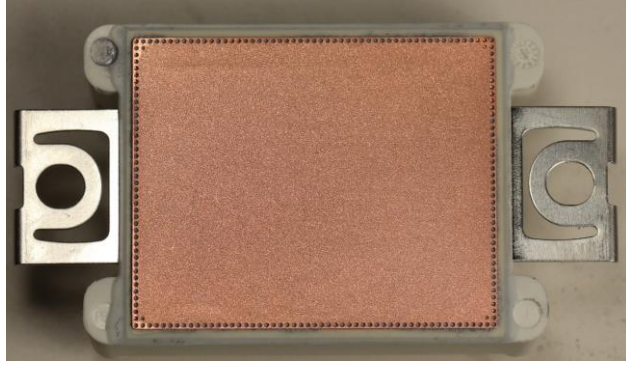


Figure 7 Clean FM3 Module

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.

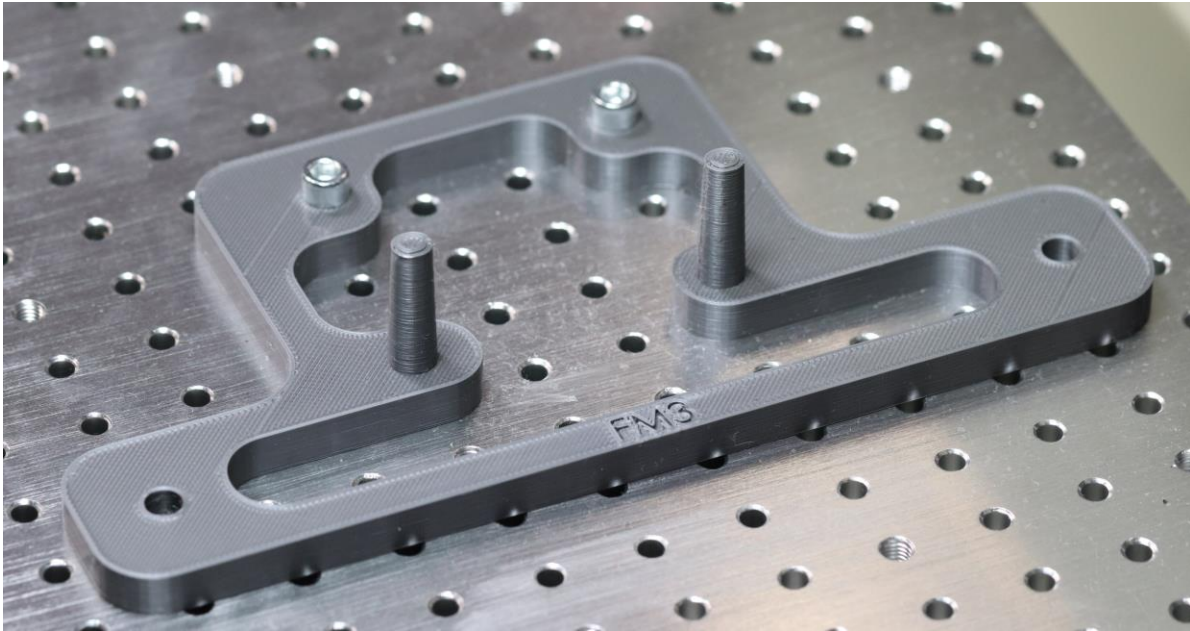


Figure 8 FM3 Module in Fixture

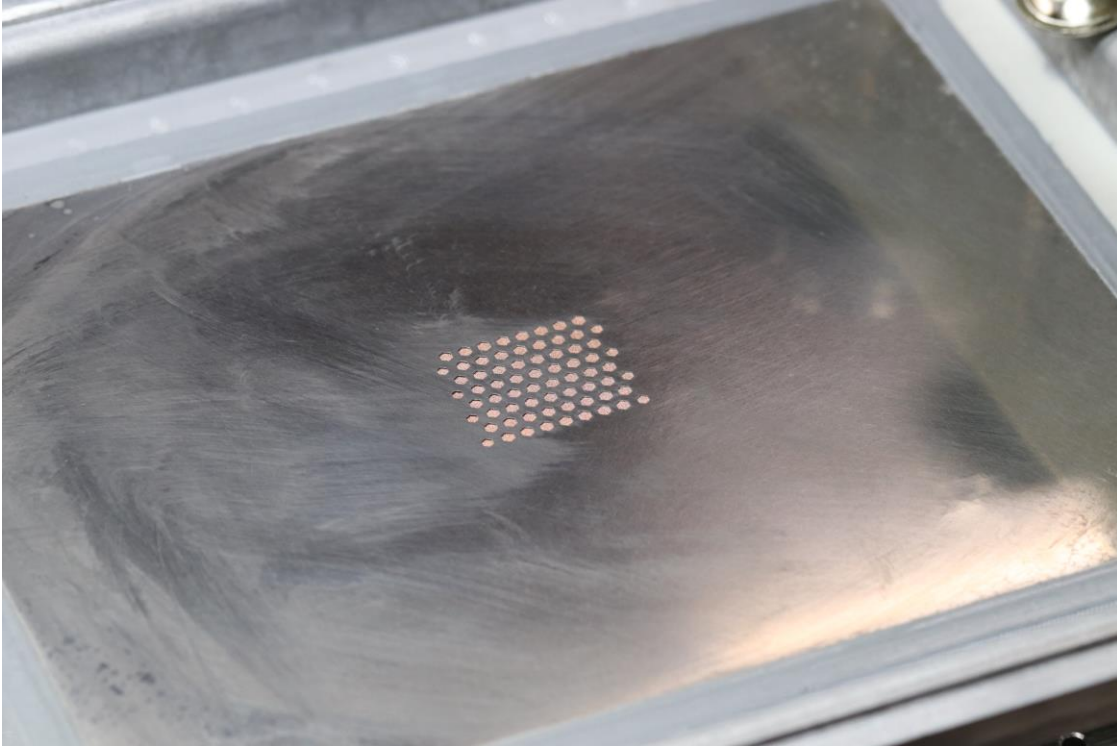


Figure 9 FM3 Module in Fixture with Stencil-to-Mounting Surface Full Contact

If the stencil aperture is too large or the squeegee durometer is too low, cupping—shown in Figure 10—can occur, and the final thickness of deposit 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 pattern area.

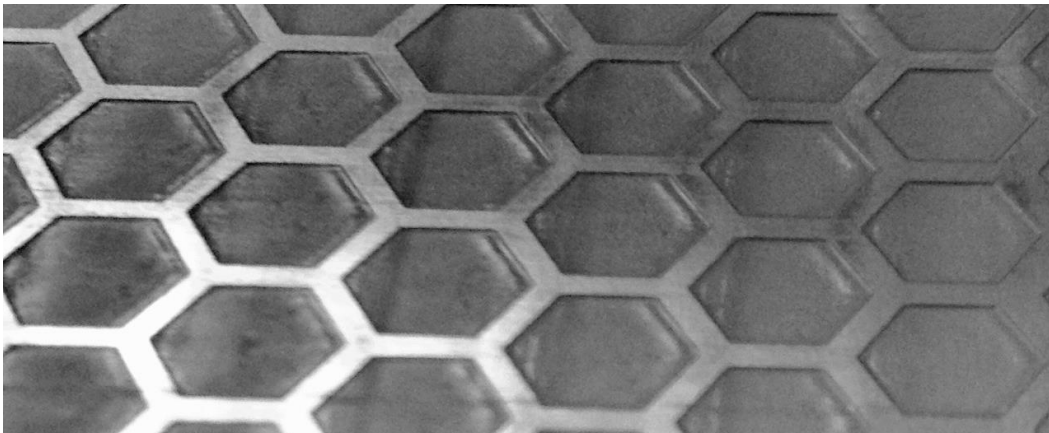


Figure 10 Cupping Due to a Low Durometer Squeegee

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 12).



Figure 11 TIM Application Amount



Figure 12 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 14).

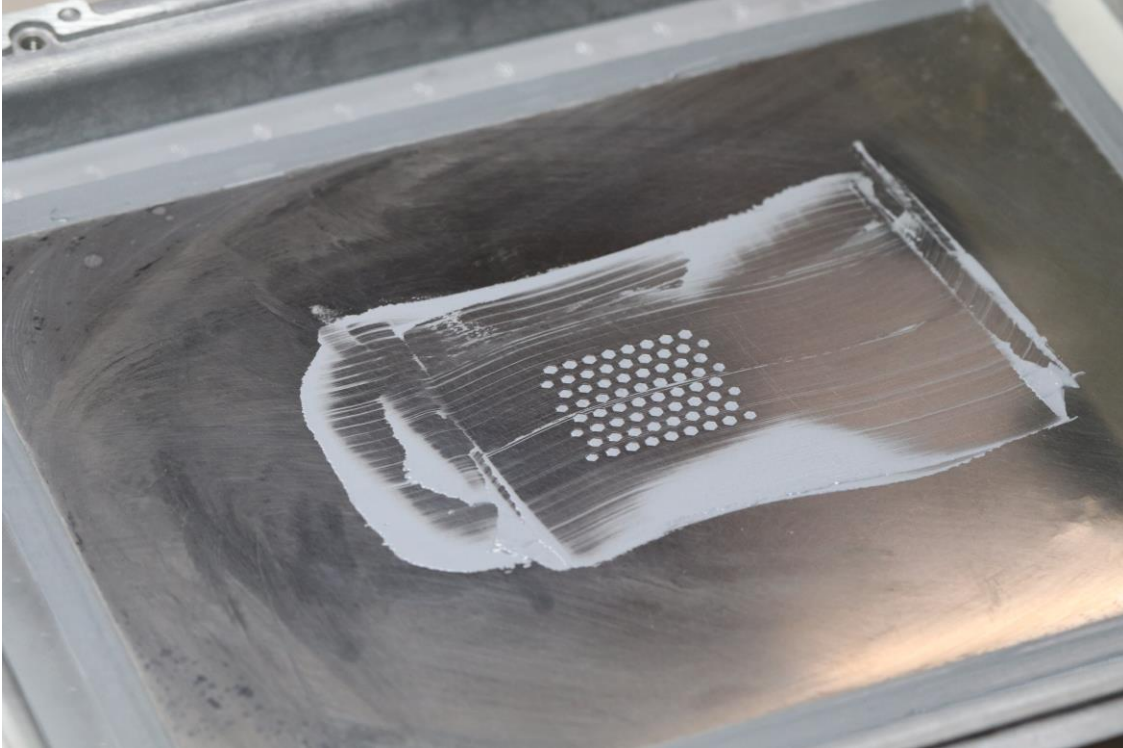


Figure 13 Correct Application of TIM to Stencil

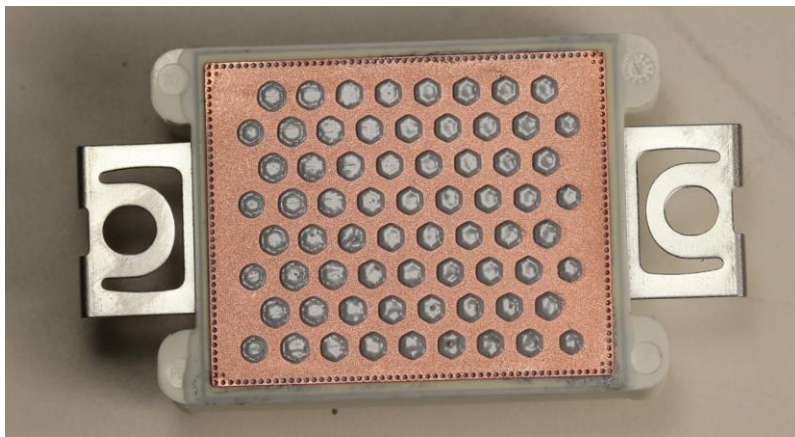


Figure 14 Inspection of Stencil-Printed TIM

2.1. 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 around. 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.)

Using one of the three methods described section 7 of Cree's [FM3 Mounting Application Note](#), Document CPWR-AN41, located at www.wolfspeed.com, attach the module to the heatsink. After heat cycling the module, it is recommended to check the torque of each mounting screw.

2.2. 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 16, 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.

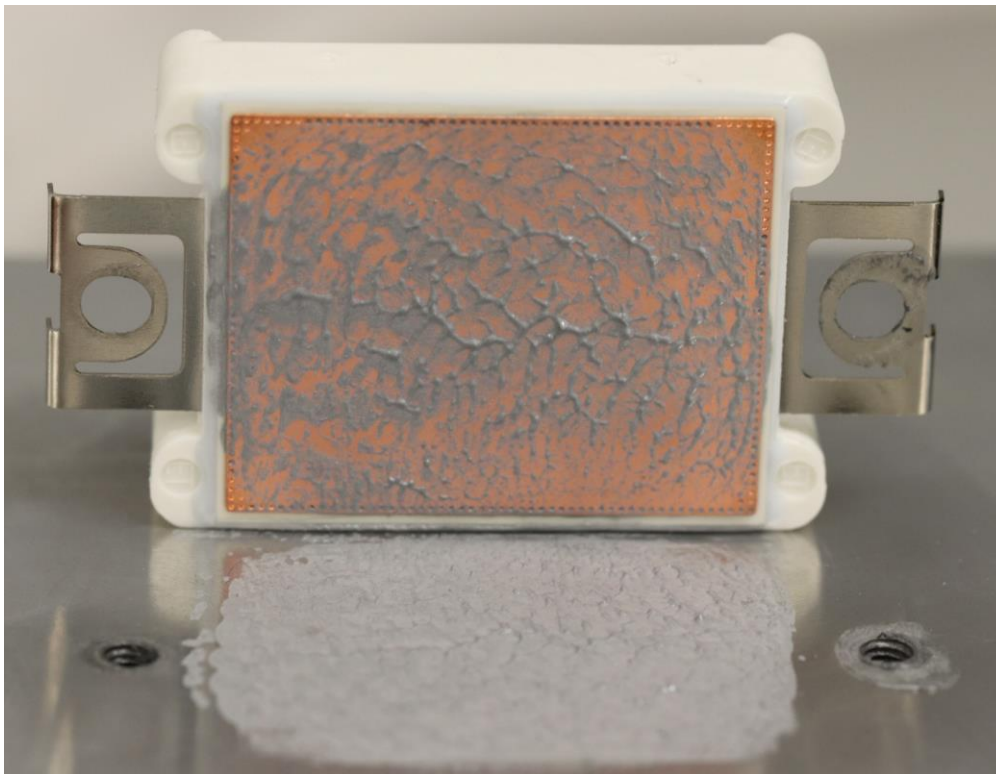


Figure 15 TIM Layer Inspection

3. Revision History

Revision	Date	Notes
1	2021-01-11	Initial Release