Thermal Interface – The Flawless Solution

Setting up a reliable thermal interface between power electronic components and a heat sink depends on choosing and applying an adequate thermal interface material (TIM). It is mandatory to ensure that the chosen material withstands the thermo-mechanical stresses as well as maintains its thermal properties throughout the predicted lifetime of the application.

Material Properties

Power electronic modules have certain special demands regarding the thermal interface. The market today offers an unmanageable diversity of materials that all, according to their manufacturer’s claims, form the perfect thermal interface in power electronic applications. To reduce the number of materials to examine, a few simple criteria turned out to be helpful. The chosen material has to be sufficient in these five ways:

- Thermally - capable to cope with temperatures from -55°C to at least 150°C
- Chemically - free of silicone, non-toxic, conformal to RoHS
- Electrically - not conductive
- Physically - insensitive to capillary effects, non-drying non-separating and not solid
- Economically- acceptable price/performance ratio

With these criteria applied, the majority of available materials can be eliminated from the list. The remaining samples have to be examined in deeper detail.

First Cycle Turn-On

After being applied to the module and mounted to a heat sink, the thermal interface has to work immediately when heat is applied. A burn-in procedure cannot be required because it is highly unwanted during assembly.

Test candidates were mounted according to their manufacturer’s recommendation and then current was applied. The chip temperature progression during the first ten cycles was recorded with the results displayed in
Figure 1:

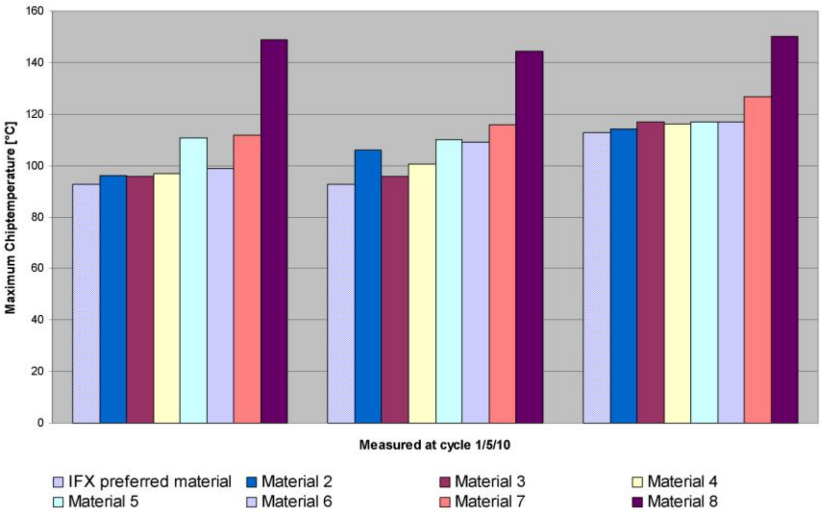

Figure 1: Measured chip temperatures during the first ten cycles with results from Cycles 1, 5 and 10 compared

Material 8 was excluded from further tests as the high temperature reached is highly detrimental to the application. Material 5 was also eliminated; despite the average thermal properties being acceptable, it’s mechanical properties made it inadequate for power electronic modules.

Reliability Tests

Power electronic modules have to survive several demanding tests during their development to make sure they suit the application’s needs. Even if the thermal interface material does not turn out to be the weak link in the chain, the thermal interface still has to survive the whole set of reliability tests done to the module. Power cycling is done to determine, whether or not the thermal interface maintains its capabilities when a certain temperature swing is applied. This test is conducted with various TIMs including the preferred solution. Current is applied to modules especially prepared for this test and a thermographic camera is used to measure the maximum chip temperature within the module. The test bench designed for this particular test is displayed in

Figure 2.

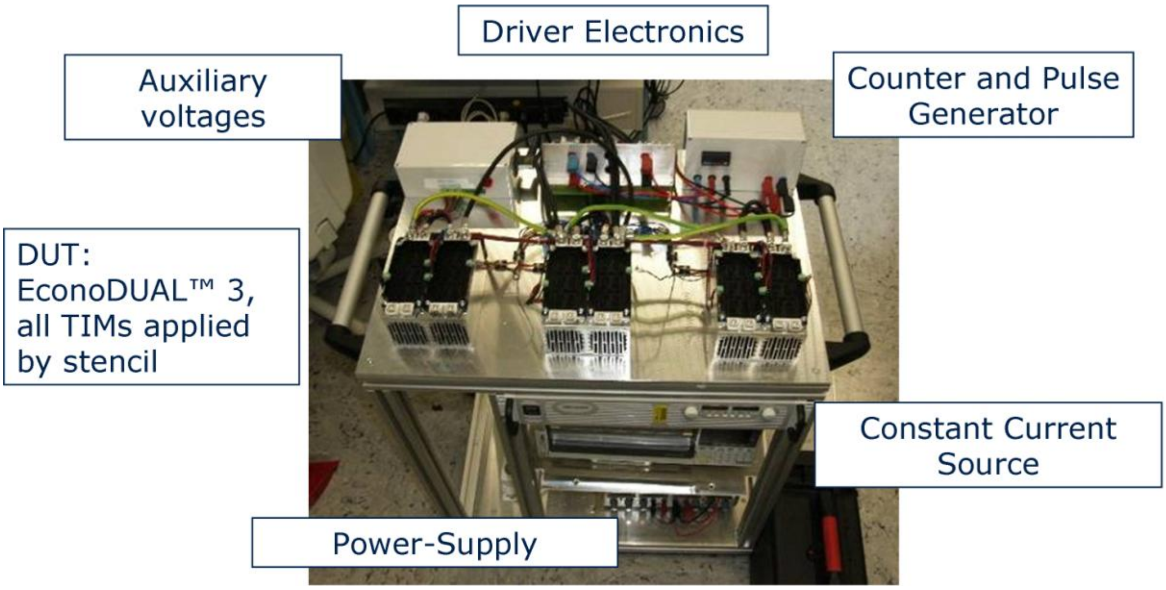

Figure 2: The Laboratory setup for TIM Power Cycling Test

To eliminate deviations due to tolerances, varying ambient temperatures and deviations within the measurement equipment, the temperature reached with the preferred solution is set as a reference representing the zero-line. The difference between the candidates under test and the preferred solution is plotted in
Figure 3

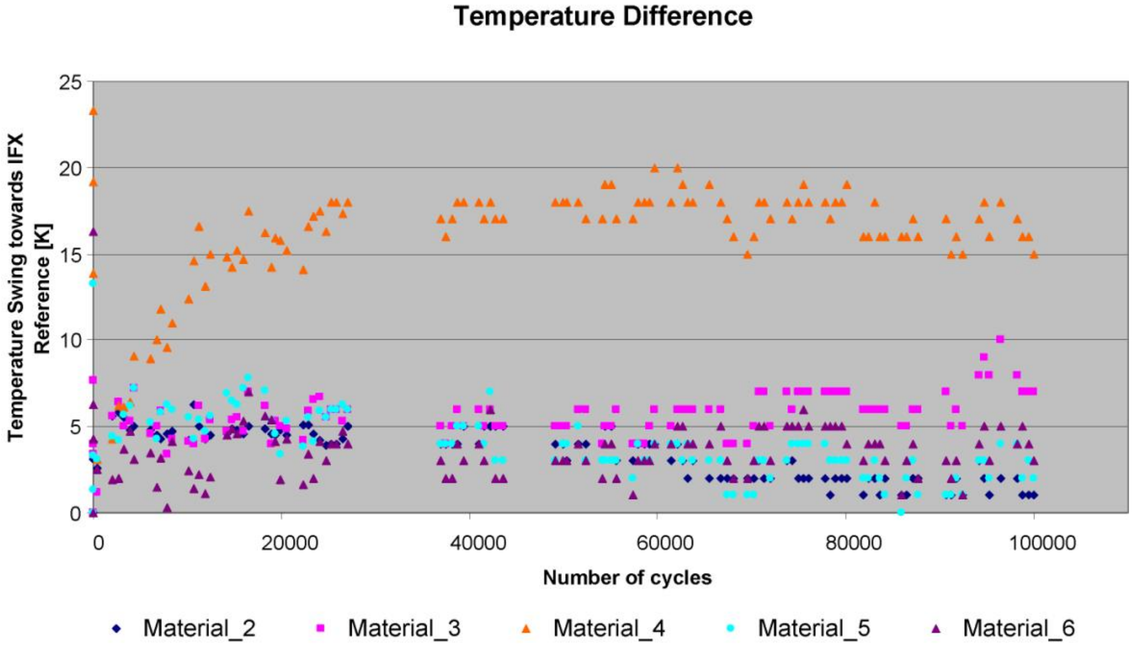

Figure 3: Differences in T_{jmax} depending on TIM. The IFX-Material as a reference represents the zero-line

As a further parameter, the modules forward voltage is recorded and displayed in Figure 4 to track if there is a significant change in the electrical behavior.

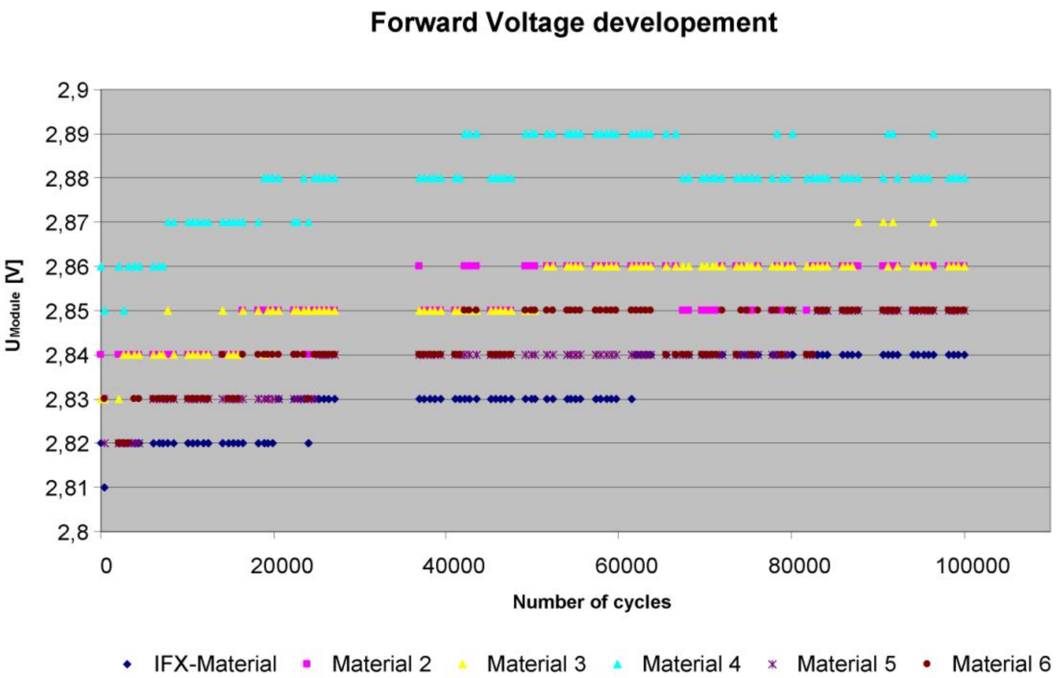

Figure 4: Forward voltage development among the test candidates showing the best result for the IXF-Solution

It becomes evident that the preferred material poses the best solution in both thermal and electrical aspects.
The thermal quality of the different interface materials can best be compared by the average temperature that the corresponding units reach during the tests; the results can be seen in Figure 5.

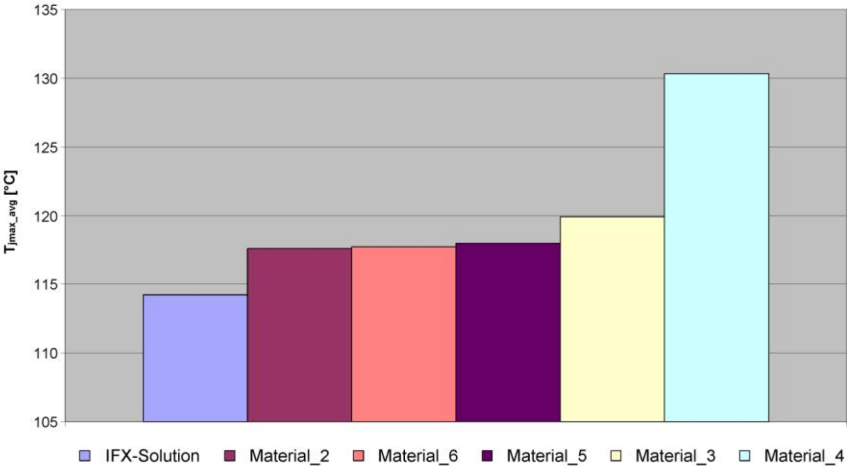

Figure 5: Maximum junction temperature for different thermal interface materials. The results show the averaged maximum temperature gained from 100.000 test cycles

Atmospheric Stress Tests

The units under test consist of modules mounted to ordinary heat sinks with the preferred thermal interface material applied. The units were cycled ten times and maximum chip temperatures were recorded in the power cycling test. Afterwards the devices were stored in climate chambers at 85% rel. humidity, 85°C for 1000 hours. The test parameters conform to IEC 60749:1996. Returning from this stress test the units were cycled ten more times and measured again. A comparison with the first measurements showed no obvious changes.
The units were additionally stored at 125°C for about 300 hours afterwards and the measurement was repeated. Here too, no obvious changes could be found.
Furthermore, testing was done to see if the torque on the screws mounting the module to the heat sink had changed. About 5.5Nm were necessary to turn the screws showing that about 90% of the torque initially applied remained. Within the measurement tolerances this only resembles a minute change.

Several conclusions can be drawn from the measurement:

- Infineon's solution works excellently starting with the first application of power even without a burn-in procedure.
- Power Cycling revealed, that the preferred solution provides the best thermal interface among the candidates as no negative values appear in the temperature difference plot in
- Figure 3.
- The chosen solution achieves the lowest electrical deviation thus contributing to excellent lifetime.
- No re-torqueing of the mounting screws needs to be done
- Evaluating thermal interface materials can only be done by long term studies. It is not helpful to evaluate an interface that only worked for a few cycles or a few hours. Material 3 in the Power Cycling test seemed fine for the first 1000 cycles, representing 50 hours of testing, but rapidly degraded afterwards.

Further aspects to pay attention to

The tests described up to now reflect the needs of the application. Besides thermal qualities, further properties the thermal interface material has to have, arise from transportation, handling and mounting of the modules with the TIM applied. To avoid damage during transportation, the preferred solution consists of Phase Change Material (PCM) that features a melting point exceeding 45°C. Even under harsh thermal conditions this is rarely reached during transport. Additionally, new boxes must be designed for packaging the modules, supporting the efforts to protect the thermally active layer. At room temperature the TIM remains solid and can even be touched without damaging it, a property that significantly eases handling and mounting.

From the manufacturer's point of view, an important point is the process of applying the TIM to the module's base plate. Here, screen printing systems have reached the highest level of confidence to form a fast, reliable process that provides reproducible results. Optic inspection after applying the material ensures that every stencil spot is filled and measurement of the spot's height makes sure the proper amount of material was applied. This way, an accurate monitoring of the process is achieved. This is a mandatory factor. Even with a stencil process, especially when done manually, misalignment of the stencil and small variations in the amount of TIM can influence the predicted temperature swing by several Kelvin.

Resume

After several years spent evaluating, testing and qualifying thermal materials, Infineon Technologies now has a promising custom made material that shows excellent results. It is targeted that by 2011 the first modules with TIM applied will be available to the marked, starting with EconoPACK™ 3, EconoDUAL™ 3 and the 62mm-family. Further modules will follow in due time after thorough tests and investigations for each additional module family have been completed successfully.