The Module Without a Baseplate: A Reliable and Cost-effective Solution

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Modules with baseplates are commonplace but cost concerns have given rise to a new breed of modules without baseplates. Figure 1 shows a flow 0 module without and a flow 2 module with a baseplate.

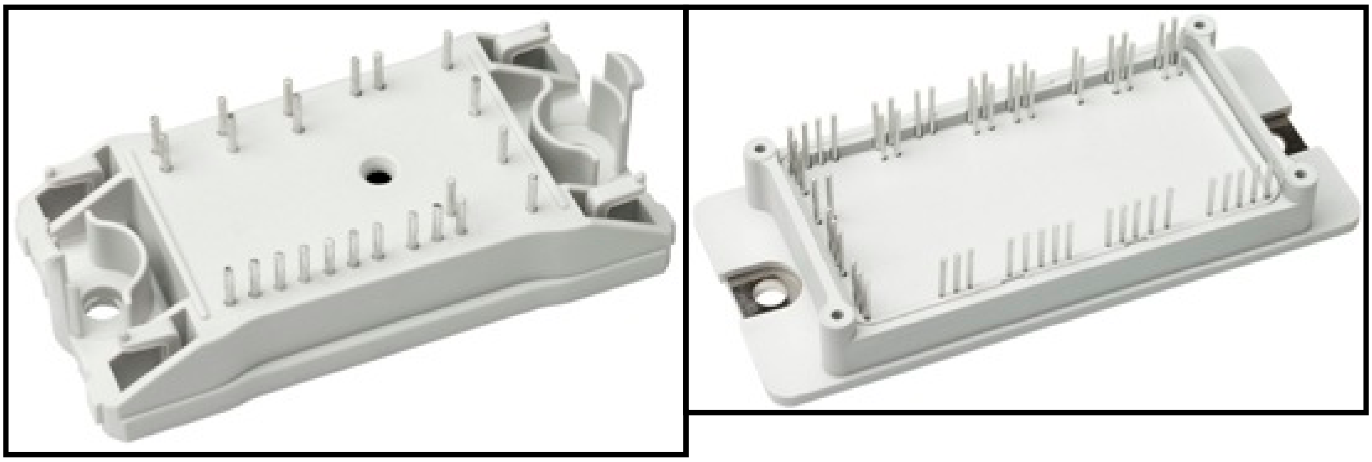


Figure 1: flow 0 without and flow 2 with a baseplate

State of the art
DBC substrates have proven their merits over many years. The advantages of DBC substrates are many: They can handle high temperature and current. Their coefficient of thermal expansion is a good match for that of silicon. They isolate high voltages and show low capacitance between the front and back sides.

Thermal conductivity

The material must conduct heat well to help keep the average temperature of the die low. Figure 2 shows a cross-section of DBC and baseplate module stacks.

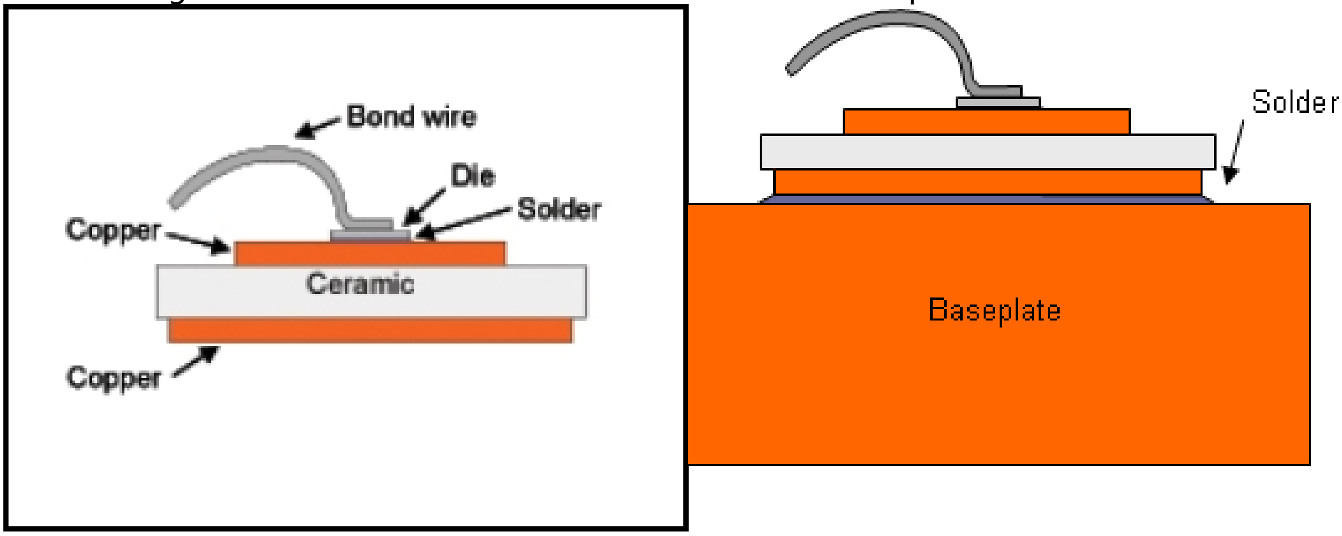


Figure 2: Cross-section of DBC and a baseplate module

Conductivities range from about 20_W/mK to 400_W/mK as shown in table 1 below.

Part	DBC module		Baseplate modules
Die [W/mK]	Silicon [148]		Silicon [148]
Solder [W/mK]	SnAg [62]		SnAg [62]
DBC [W/mK]	Al_2O_3 [25]	AlN [155]	Al_2O_3 [25]
Solder [W/mK]			SnAg [62]
Baseplate [W/mK]			Cu [401]

Table 1: Thermal resistance of module materials @ 25 °C

The coefficient of thermal expansion

Thermal expansion is the tendency of a material’s volume to change in response to temperature change. Given the same temperature increase for two materials, copper expands about six times more than silicon. Table 2 below shows key materials used in power modules.

Part	DBC module		Baseplate modules
Die [10^{-6}/K]	Silicon [2.8]		Silicon [2.8]
Solder [10^{-6}/K]	SnAg [22.1]		SnAg [22.1]
DBC [10^{-6}/K]	Al_2O_3 [8.2]	AlN [4.5]	Al_2O_3 [8.2]
Solder [10^{-6}/K]			SnAg [22.1]
Baseplate [10^{-6}/K]			Cu [16.5]

Table 2: The CTE of module materials @ 25 °C

The CTE of Al2O3 is closer to silicon than copper. The CTE of AlN is closer to that of Si, which reduces stresses in die attach materials. However, the stresses are actually higher in the joint between the copper baseplate and DBC because of the greater difference between the net CTE of the Al2O3 DBC and the copper baseplate.

A mismatch in CTE can cause mechanical and fatigue failure. In IGBT power modules, the joint between the DBC and baseplate is much larger than the joint between the semiconductor and DBC, so it is more prone to failure. Consequently, the DBC may delaminate from the baseplate, which can cause thermal resistance to increase. Residual thermal stresses in the DBC-baseplate stack can also cause a bimetallic effect that bows the module. Pre-bent, convex baseplates such as those used in flow 2 modules can compensate for this packaging-induced phenomenon.

Wear-out failures
The failure can occur between every material with different temperature expansion coefficients.

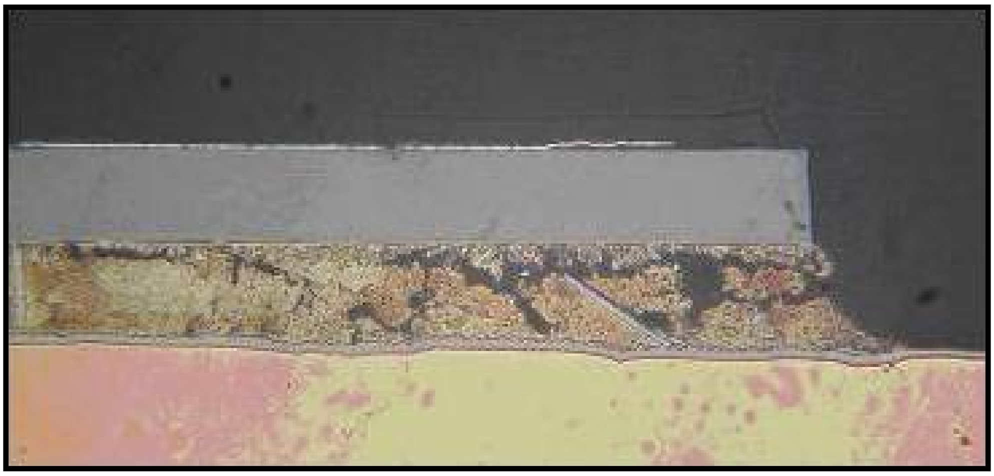
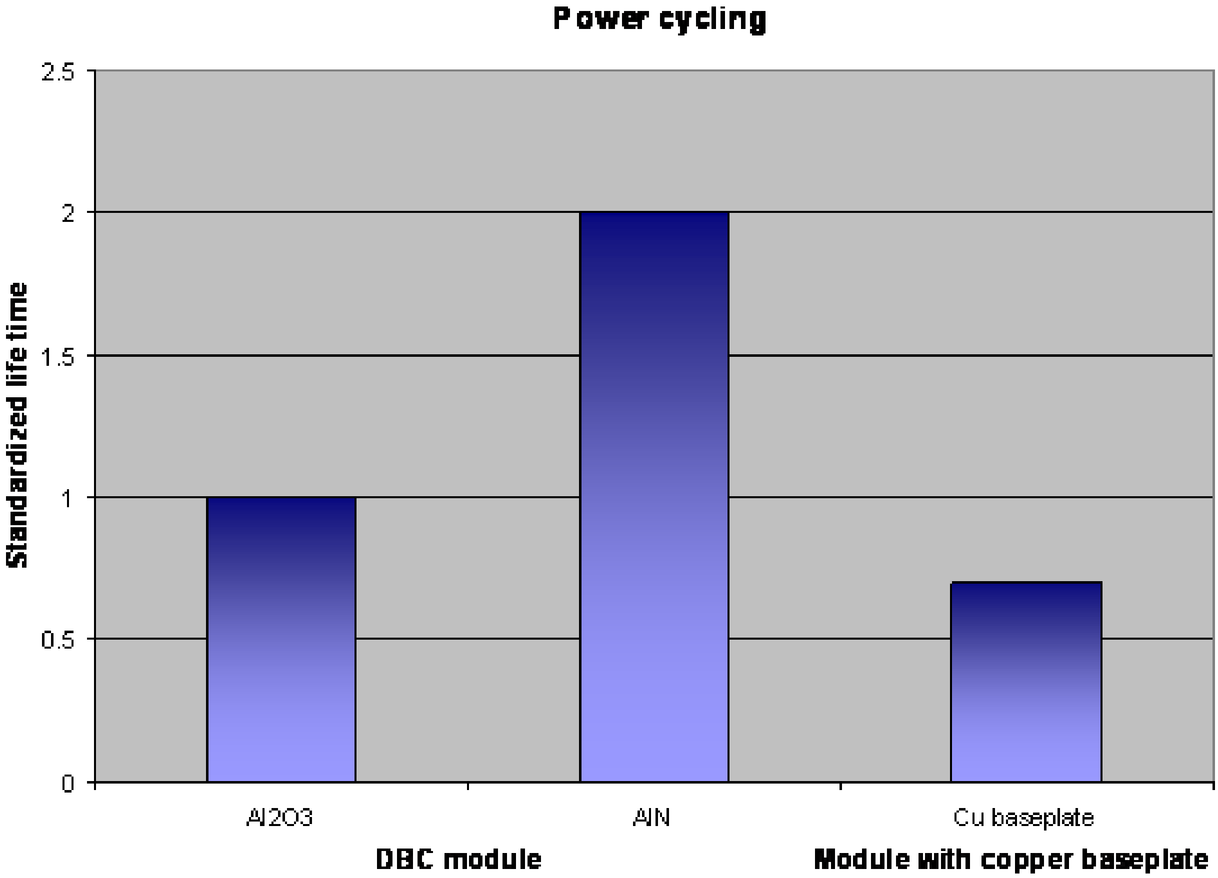


***Figure 3**: A delaminated solder layer*

Delamination starts at the edges of the solder joint and expands inward. A larger joint is exposed to greater tensile forces, so small chips and solder joints are less likely to delaminate.
There are several ways to counteract the effect of thermal expansion. Smaller chips may be paralleled, or the module may be oversized so that it generates less loss and therefore less heat.

The reliability of different approaches
Vincotech subjects each module to battery of quality and reliability tests. The chart below shows reliability data standardized to a DBC module equipped with an Al2O3 DBC. Test conditions for all three modules were equal. Chip size and number of chips were also identical.



This description of the CTE phenomenon and how it relates to reliability would not be complete without mentioning heat-driven expansion. The solder joint must absorb the silicon, DBC and baseplate's expansions without failing. The challenge is to design a solder joint thin enough to ensure a low drop in temperature, yet thick enough to absorb the movement of joint materials.

Having examined different variants of modules, we can draw the following conclusions: The longest component life may be achieved by keeping temperature ripple low. The load and environmental conditions are key factors. The smaller the number and the lesser the extent of thermal expansions, the greater the reliability. The CTE of materials should match. If thermal capacity is not an issue, a module without a copper baseplate is the right choice.

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