STABLCOR®: Groundbreaking PCB and substrate material

By Carol Burch and Kris Vasoya

The weight, rigidity, and thermal properties of PCBs are of paramount importance to many system designers. Similarly, these same parameters are of vital interest to integrated circuit designers for the IC substrate.

Now, a new composite laminate has been introduced to the marketplace that offers unique rigidity and thermal advantages to both system and IC designers. Moreover, it offers these advantages without the additional weight penalty of CIC (Copper Invar Copper), CMC (Copper Moly Copper), and Heavy Copper.

In this article, Carol and Kris discuss STABLCOR in detail, the groundbreaking new composite laminate from ThermalWorks.

Composite PCBs and device substrates

The STABLCOR laminate is composed of a carbon composite material. A STABLCOR composite laminate layer is used as a plane layer (non-signal carrying layer) in a stack-up with other dielectric layers to construct a composite PCB or device substrate. The properties of several raw PCB materials are shown in Table 1.

STABLCOR properties

The STABLCOR properties are summarized below, and are described sequentially in this article:

- Density – grams per cubic centimeter.

The new material density (and therefore weight) is approximately equivalent to fiberglass.

- Thermal Conductivity – Watts per meter • Kelvin.

The new material can spread heat at a 620 W/m•K transfer rate, which is far greater than for traditional materials.

- Tensile Modulus – MSI (1,000,000 PSI).

The new material is much more rigid than traditional materials.

- Thermal Expansion – Represented by the Coefficient of Thermal Expansion (CTE), which is expressed in parts per million per °C. The new material has a very low negative CTE, so it contracts very little as temperature rises. Traditional materials expand considerably as temperature rises.

Density – The weight advantage

The Dielectric Constant (Dk) of the carbon composite material is approximately 13.4, which makes it electrically conductive. This is why the carbon composite laminate layer is used as a plane layer, and not a signal-carrying layer. A manufacturing process is used to insulate copper vias from the STABLCOR layer.

Because of its electrical conductivity, the material is suitable for use as the ground layer instead of a traditional copper layer. As shown in Table 1, the composite material (density 1.85 g/cc) has a tremendous weight advantage over heavy copper (density 8.92 g/cc) and CIC (density 9.9 g/cc). This is of great importance to any project where weight is a design factor.

Thermal Conductivity – Dissipation without the weight

Most designers put heavy copper near the center of the board so as not to create any expansion mismatch problems near the surface. The problem with this solution is that it creates a much longer thermal path for the heat to travel from the surface to the center of the board. With STABLCOR directly next to the surface layer, there is a much shorter thermal path as shown in Figure 1.

Heat will travel from the ground pin of the device through the copper vias and one dielectric layer before reaching the STABLCOR layer. After the heat reaches

RAW MATERIAL	DENSITY (g/cc)	THERMAL CONDUCTIVITY (W/m·K)	TENSILE MODULUS (MSI)	CTE (ppm/°C)
ST 600	2.20	620.0	130.0	-1.15
ST 325	2.17	325.0	114.0	-1.15
ST 10	1.76	8.0	34.0	-1.10
FR4	1.80	0.3	2.4	17.00
POLYIMIDE	1.70	0.3	3.0	17.00
COPPER	8.92	385.0	12.0	17.00
ALUMINUM	2.70	240.0	10.2	24.00
CIC	9.90	108.0	19.0	4.00

STABLCOR® values represent data from raw fibers

Table 1

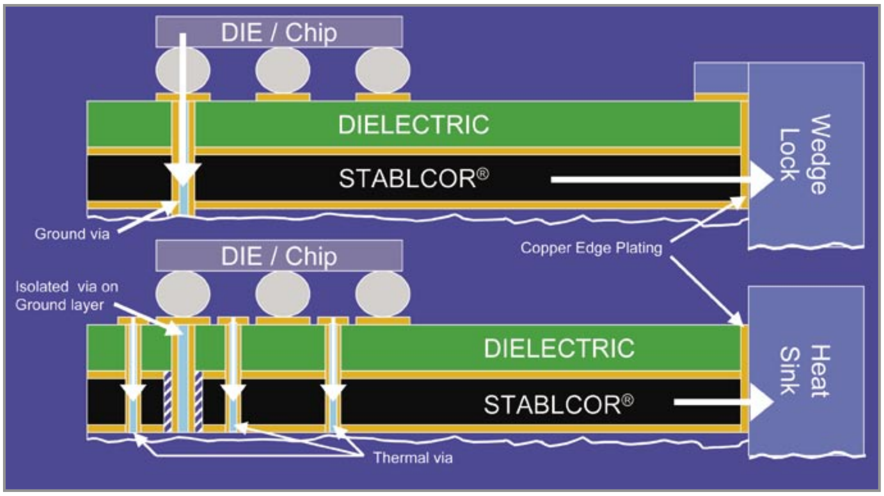


Figure 1

the layer, it spreads at a 10 to 600 W/m•K transfer rate depending upon the composite laminate selected.

As shown in Table 1, the laminate is available in three grades that are denoted by their approximate thermal conductivity: ST10, ST325, and ST600. Also, note that the thermal conductivity of all three grades far exceeds that of FR4. In addition, the thermal conductivity of ST600 far exceeds that of copper.

As a thermal conductivity example, a thermal scan of two memory modules after a 50 minute RAM Stress Test is shown in Figure 2. Both modules use the same design, DRAM, and discrete components. The front module memory devices are mounted to a composite PCB with a STABLCOR layer, while the rear module memory devices are mounted to a standard FR4 PCB.

As shown in the figure, the STABLCOR module is 15 °F to 18 °F cooler than the FR4 module. This application exhibits significant cooling benefits even though this is the least effective use of STABLCOR since the memory module is not thermally connected to a much larger mass.

Tensile Modulus – Rigidity without the weight

The tensile modulus of the composite laminate is magnitudes greater than glass. When composite laminate layers are included in a FR4 or Polyimide multilayer PCB, the stiffness is increased 2 to 10 times (depending on the volume ratio of composite laminate material vs. other material).

For PCBs, the increased stiffness may eliminate the need for mechanical reinforcements or stiffeners. For devices, it may increase the yield in high I/O components due to the increase in solder joint reliability. For any application, the increased stiffness increases reliability in a high shock and vibration environment.

Thermal Expansion – Stability without the weight

The composite laminate has a very low negative CTE, so it contracts slightly as temperature rises. Traditional materials expand considerably as temperature rises. It naturally follows that the thermal expansion of the new material can greatly benefit PCB and integrated circuit designers.

CTE mismatch with flip-chips

Wire bonded packages no longer meet the speed requirements of newer ICs, so the industry has developed flip-chip packages. With this technology, the die pads are directly connected to the substrate pads using solder balls, or the more expensive solder columns (Figure 3).

Because of the direct connection, the CTE of the die must be close to the CTE of the substrate. As shown in the figure, the CTE of a typical die is 2.5 ppm/°C, and the CTE of a typical flip-chip substrate is 6 to 8 ppm/°C. The CTEs are relatively close, which results in a reasonably reliable die-to-substrate connection.

However, there is a CTE mismatch between the substrate and the PCB. The flip-chip substrate with a CTE of 6 to 8 ppm/°C is usually mounted to a standard FR4 PCB with a CTE of 17 to 19 ppm/°C. This resulted in a considerable CTE mismatch, and the reliability of the solder connection used to mount the flip-chip suffered due to expansion. This led to the replacement of the solder balls with more expensive solder columns in order to improve reliability.

If a composite PCB includes STABLCOR layers, a designer can eliminate the solder columns and the ensuing expense, and tailor the CTE of the PCB to more closely match the CTE of the flip-chip substrate.

CTE mismatch with direct die mounting

The technology to mount dies directly to the PCB now exists as shown in Figure 4. With this technology, the typical die with a CTE rate of 2.5 ppm/°C is directly mounted to a standard FR4 PCB with a CTE of 17 to 19 ppm/°C. This considerable CTE mismatch can lead to device separation from the PCB and other multiple failure modes.

If a composite PCB includes STABLCOR layers, a designer can tailor the CTE of the PCB to more closely match the CTE of the die.

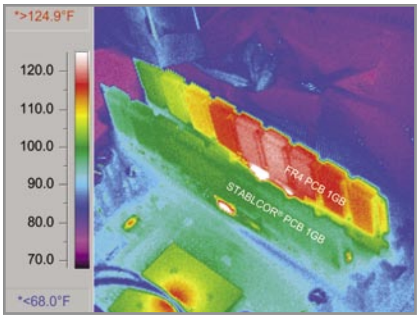


Figure 2

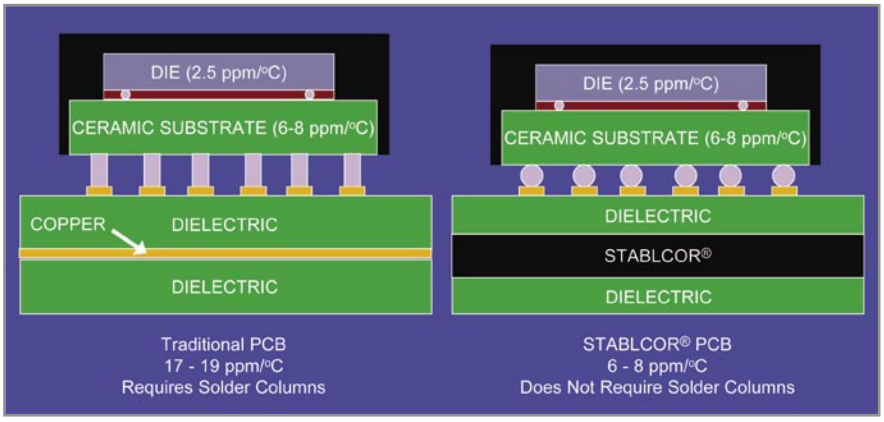


Figure 3

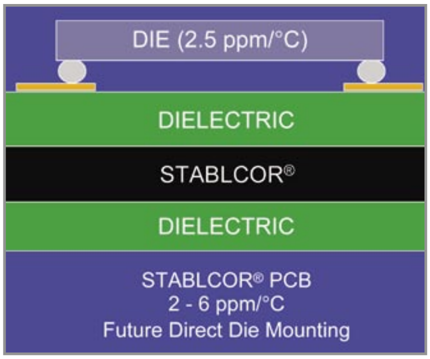


Figure 4

CTE test results

The results of a CTE test conducted on a composite PCB by Auburn University is shown in Figure 5. The test compared the CTE of a composite PCB with a STABLCOR ST325 layer to that of a standard FR4 PCB. Both PCBs did not have any mounted devices. As shown, the CTE of the STABLCOR composite PCB averaged less than 3 ppm/°C for temperatures less than 150 °C (the glass transition temperature of FR4).

In another CTE test, the lab mounted a flip chip to the STABLCOR and FR4 composite PCB. Again, CTE of the STABLCOR composite PCB was less than 3 ppm/°C for temperatures less than 150 °C.

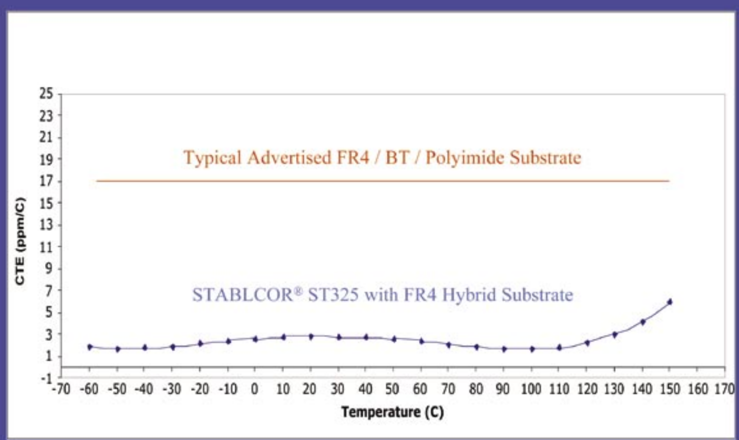
STABLCOR design aides

There are several STABLCOR laminate design guides and application specific guidelines available. In addition, there is a complete simulation software library available that supports three top thermal simulation programs: FLOTHERM (Flomerics), Icepak (Fluent), and TASPCB (Harvard Thermal).

With the library, designers do not have to build a prototype PCB for initial thermal data. Instead, the designer can build up a PCB through simulation and immediately observe the thermal advantages.

Summary

Conduction cooling for composite PCBs no longer has to be achieved with heavy copper layers. STABLCOR, a much lighter weight material that offers a thermal and stiffness advantage is immediately available. Ω



STABLCOR® + FR4

Temp (°C)	CTE (ppm/°C)
-60	1.95
-50	1.79
-40	1.83
-30	1.98
-20	2.19
-10	2.42
0	2.63
10	2.78
20	2.86
30	2.85
40	2.77
50	2.61
60	2.40
70	2.17
80	1.95
90	1.79
100	1.75
110	1.89
120	2.31
130	3.07
140	4.27
150	6.03
Average	2.56

Figure 5

Carol Burch *is the Marketing Manager for ThermalWorks. She has more than 25 years of experience with semiconductor design, sales, and marketing.*

Kris Vasoya *is one of the original founders of ThermalWorks and is credited as the inventor of ThermalWorks STABLCOR technology. Kris currently serves as ThermalWorks Executive Vice President of Engineering & Technology. Kris has considerable expertise in material sciences and viable applications. Kris holds a BS in Mechanical Engineering from Sardar Patel University, India.*

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