

Thermally Conductive Composites: Filling the Performance-Cost Gap in Thermally Sensitive Printed Circuit Boards

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Designing a thermally sensitive PCB, one could be forgiven for thinking that options for base materials are limited to products like an insulated metal substrates (IMS) or the traditional FR4. Both occupy opposing ends of the performance/price spectrum and both are commonly used. There is another option however; thermally conductive *composite* copper clad laminates do provide new thermal options that are seldom applied in North American lighting and heat sensitive designs.

When is a thermally conductive composite base laminate a better choice than IMS or FR4 for a lighting PCB design? The general thinking is that these composites (enhanced CEM-3) fill the gap between the high cost/high thermal performance of copper-clad aluminum (IMS) and the low cost/low thermal performance of an FR4 substrate. From a pure cost perspective, it's true. In general you could expect to pay 20% -25% more for a CEM-3(TC) product over a similar FR4 construction, but the CEM-3(TC) cost is well under a third of the price of your standard IMS laminates. What about the performance gap? CEM-3 is old technology, practically made obsolete 15 years ago by new efficiencies in PCB manufacturing the ubiquitous and more mechanically robust low cost FR4 in Asia.

A quick way to understand the thermal performance differences is this:

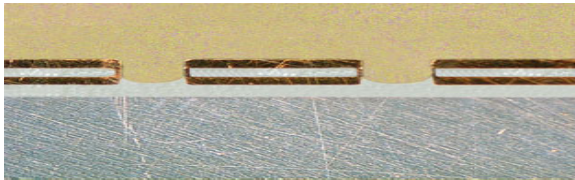
FR4 is composed of several layers of woven glass and epoxy resin, which is a great insulator both electrically and thermally, so its not ideal when excessive surface heat is your concern. The positive aspects are FR4 is it's easy to get and inexpensive, it can be processed cheaply at any PCB shop, and from a design perspective drilling and plating thermal vias is easily done. These vias move the heat efficiently giving the finished board much better thermal conductivity value than appears on its datasheet. These are strategies that are commonplace and necessary on an FR4 base because at 0.4W/mK most PCB's would delaminate under the increasing surface heat in most lighting designs. Fiberglass is an insulator, so without thermal vias today's boards would quickly exceed their operating temperatures. The one negative of an FR4 substrate is that the woven glass thermal limitations can restrict even the best designs – and extra drilling and plating costs money!

FR4 Woven Glass Cross Section



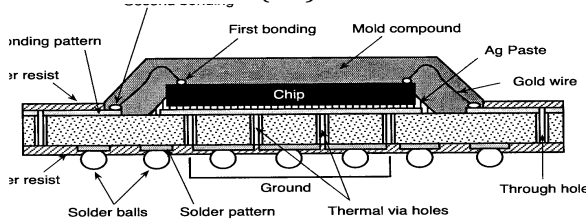
The insulated metal substrate (IMS) on the other hand is a plate of an aluminum or copper alloy with a thin (.003”-.005”) dielectric layer (either a resin-coating or woven glass) between the etched copper surface and its metal base. The dielectric layer is as thin as electrically possible to allow the heat to move to the very thermally conductive metal substrate (aluminum or copper) and to then dissipate into its environment. Of course the big positive for the IMS is thermal performance, nothing moves the heat better than the aluminum or copper base and the thin dielectric transfers it from the surface quickly. The downside is the price and manufacturing limitations. Although the price of a bare panel of IMS has dropped a lot in the last 5 years, it is still 4X the price of a panel of FR4. Not every PCB shop is qualified to manufacture using IMS either, and it’s a process that is hard (read: expensive) on the equipment . There are also fewer manufacturers of IMS base materials and so any given construction may stretch out your lead-times to get product in the pipeline. Another limitation is plating, metal vias will not plate easily so your “playing surface” is limited to one plane. On the bright side, the thermal dielectrics continue to improve so heat from the surface is transferred quicker than ever 3.0 and 5.0W/mK are becoming more common and the technology continues to improve filling the need for higher and higher performance IMS products.

IMS with coated dielectric



The CEM-3(TC) base material is a non-woven blend of glass and epoxy. So although it has the same building blocks of FR4, by the fact that it is a “molded aggregate” instead of a series of woven insulating walls allows manipulation in the form of thermally conductive fillers. The thermal performance possibilities of a TC composite base material can vary widely based on the circuit design. As an example, Chang Chun’s CCP308(TC) starts with a thermal conductivity of 1.5W/mK, once you add to the cooling design strategies like thermal vias (CEM-3 is platable) and a copper-clad groundplane the thermal transfer from the surface can rival that of the IMS at a fraction of the cost. From an accessibility perspective, all PCB shops are able to manufacture with CEM-3 (TC) using traditional FR4 parameters, so your

Non-Woven CEM-3(TC) with thermal vias:



options are opened. Another important factor is that the composites can be punched instead of drilled and/or routed. For those few North American PCB makers with punching capability, or if you are depending on Asian production facilities with punching capability, processing costs could drop dramatically depending on design choices.

So its true, the enhanced CEM-3 products do open a new avenue to explore as cost and thermal performance are balanced at design. Considering it a base material that bridges the gap in both cost and performance is accurate. It is not new technology, just *newly-applied* technology that creates interesting opportunities for the thermally concerned PCB designer. Enhanced CEM-3 products have grown in popularity in Asia for the reasons described above, and several North American OEMs have seen the advantages and found the appropriate applications for this new-old technology in innovative ways.

Materials testing for LED Thermal Condition - Heat rise.

Comparing base IMS to std FR-4 and Thermal enhanced CEM-3

Test Samples have 3 x Cree CLN6A LEDs - 60.5 - 101.8 lm - 350mA nom - 1200mW each

Readings are Temperature in Deg. F.

Samples are with Copper Fill in circuit ground area - No Vias

Solid Ground Plane on Bottom of CEM-3 & FR-4, Bare AL on IMS parts

| Material | Temperature @ 10 Minutes | Description |
|-----------|--------------------------|-------------|
| 0.039 IMS | 101.3 | IMS AL 5052 |
| 0.059 TC+ | 113.5 | CEM-3 1/1 |
| 0.061 FR4 | 143.3 | DS FR-4 1/1 |

