## **Industry Developments:**

### **Thermally Conductive PCBs**

A wide range of printed circuit board materials are available for electronic assemblies requiring heat management characteristics (high-power devices, RF and wireless, lighting/LED boards, etc.). In widening use are metal-clad PCBs with a standard dielectric, and metal cores of various thicknesses of aluminum and copper. Providers of these PCBs offer tight machining tolerances and high-quality fabrication services for effective thermal management. Many industry trends, such as cost reduction pressures, reduced footprints, and reduced weight, are counterbalanced by the need for higher circuit density to provide increased functionality. The end result is an increase in heat generated—and a growing need for improved, costeffective thermal management.

Circuit board thermal conductivity is often neglected as a potential area to improve heat transfer, since this has historically not been a controllable design option. The primary purpose of these materials is to provide electrical isolation of the various components and traces. This has yielded materials that are also good thermal insulators, which trap heat within the active components of the board.

By modifying the base properties of these materials, Arlon's StaCool<sup>™</sup> laminates provide not only the electrical insulation required for typical circuit boards, but also improve heat transfer rates relative to traditional materials. [1] StaCool<sup>™</sup> copper clad laminates (CCL) and prepregs (ML) offer class leading thermal conductivity with

outstanding electrical insulation performance, all the while permitting multi-layerability. Utilizing high Tg (170°C) resin combined with advanced ceramic fillers, the StaCool<sup>™</sup> CCLs and PPs can be used in place of standard FR-4 laminates and prepregs, providing the designer with the versatility to create unimaginable high current density, high power circuits without the need for external heat sinks or exterior cooling. StaCool<sup>™</sup> laminates and prepregs are offered in 3, 4, 6, and 8 mil single ply constructions or any combination thereof and can be laminated with any copper foil type or weight up to 6 oz. StaCool<sup>™</sup> metal clad laminates (MCL) combine StaCool<sup>™</sup> prepregs with copper foil and an aluminum base to create a thermally conductive, electrically isolative substrate. Aluminum substrates from 0.032" and greater can be ordered in a variety of alloys including 5052-H32 and 6061-T6, amongst others.



Figure 1: StaCool<sup>™</sup> Thermally Conductive Metal Clad Laminates for Multi- or Single- Layer Printed Circuit Board Fabrication [1]

#### **Desirable PCB Material Characteristics**

What are desirable PCB material characteristics when operating with higher levels of current or RF power? Simply put, dielectric materials rated for higher temperatures can generally handle higher DC or RF power levels than can materials characterized for lower-temperature operation. For example, FR-4 is a popular PCB substrate material, but it is characterized by low thermal conductivity of 0.2 W/m/K—a warning sign against its use in circuits with high DC or RF power. (Some PCB material data sheets may also provide a material's thermal resistance, in °C/W.) FR-4 has a CTE in the z-axis of typically 175 ppm/°C and its Tg can range from +110 to +135°C. The tangent loss is typically 0.020 at 1 MHz and 0016 at 1 GHz. Typical values of FR-4 relative dielectric constant are 4.70 at 1 MHz and 4.34 at 1 GHz.

#### **Avoiding Hot Spots**

In a high-frequency circuit, heat can come from the environment (the ambient temperature) or from DC and RF sources: from the flow of supply current, for example, or from RF input power to the circuit or power generated by an active device, such as a power transistor. Ideally, heat will flow away from the circuit, without creating any "hotspots." Excessive temperatures can cause damage to a PCB's dielectric material, and even cause copper transmission lines to delaminate from the dielectric material. Creating models that predict thermal effects on PCBs can help prevent creating inadvertent hotspots and potential damage to a circuit. [2]

#### **Laminates and Prepregs**

Laird Technologies provides the Tlam<sup>™</sup> thermallyconductive PCB substrate system that provides 8-10 times the heat dissipation compared to conventional FR4-based PCBs. The miniaturization of electronic devices continues to pack more and more power into smaller and smaller packages. Tlam<sup>™</sup>'s dielectric provides electrical isolation, thermal transfer and adhesion layer for the substrates. Tlam<sup>™</sup> SS is a single-sided PCB substrate. Tlam<sup>™</sup> DS is a double-sided copper laminate, and Tlam<sup>™</sup>



Figure 2: Tlam<sup>™</sup> IMPCB LLD From Laird Technologies is Designed for Bright and Ultra-Bright LED Module Applications. [3]

PP is the dielectric used to bond multi-layer PCB together.

Tpreg<sup>™</sup> 1KA from Laird is a thermally conductive, electrically insulating prepreg. The Tlam<sup>™</sup> thermally conductive printed circuit boards use Tpreg<sup>™</sup> 1KA dielectric sheets in conjunction with copper foil and an integral metal base plate to provide a circuit board laminate that has superior thermal management capabilities compared to conventional FR4-based printed circuit boards. Free-standing Tpreg<sup>™</sup> 1KA dielectric sheets facilitate multi-layer and FR4-hybrid PCB construction.

#### **High Frequency Laminates**

RT/duroid<sup>®</sup> 6035HTC high frequency materials from Rogers Corporation are ceramic filled PTFE composites for use in high power RF and microwave applications. [4] With a thermal conductivity of almost 2.4 times the standard RT/duroi®d 6000 products, and copper foil with excellent long term thermal stability, RT/duroid® 6035HTC laminates are an exceptional choice for high power applications where high reliability is required, including in circuits for military and aerospace systems. Rogers advanced filler system enables excellent drillability, reducing drilling cost as compared to standard high thermally conductive laminates which use alumina fillers. RT/duroid 6035HTC circuit materials are ideally suited for high-frequency, high-power circuits, including amplifiers, couplers, filters,



Figure 4: Thermal Clad Insulated Metal Substrate (IMS®) from Bergquist Can Be Used For High Watt-Density Surface Mount Applications Where Die Size Is Reduced and Heat Issues Are A Major Concern. [5]

Figure 3: Rogers RT/duroid® 6035HTC Laminates Incorporate a Unique Filler Material to Achieve a Relative Dielectric Constant of 3.5 in the Z-Axis at 10 GHz with Extremely High Thermal Conductivity of 1.44 W/m-K. [4]

and power combiners/dividers. The high thermal conductivity, combined with a low loss tangent of 0.0013 at 10 GHz, enables circuit designers to optimize gain and efficiency in high-power amplifiers.

#### **Insulated Metal Substrates**

Thermal Clad Insulated Metal Substrate ((IMS®) was developed by Bergquist as a thermal management solution for today's higher wattdensity surface mount applications where die size is reduced and heat issues are a major concern. [5] Benefits from using Thermal Clad IMS® include lower operating temperature, reduced printed circuit board size, increased power density, and extended life of the cooler dies. The IMS® allows the use of few heat sinks and related mounting hardware, along with thermal interface materials. These metal based substrates also replace fragile ceramic substrates with greater mechanical durability.

There are several options available for thermal management of Power LEDs. The most critical thermal path in the stack is the one with the highest thermal resistance. Good practice suggests that you reduce the thermal resistance of that layer with Thermal Clad dielectric instead of FR-4. The key to Thermal Clad's superior performance lies in its dielectric layer. This layer offers electrical isolation with high thermal conductivity and bonds the base metal and circuit foil together. Other manufacturers use standard prepreg as the dielectric layer, but prepreg doesn't provide the high thermal conductivity and resulting thermal performance required to help assure the lowest possible operating temperatures and brightest light output for high-intensity LEDs. Thermal Clad circuit board materials are available from The Bergquist Company in four different thermal conductivities, High Power Lighting (HPL), High Temperature (HT), Low Modulus (LM) and Multi-Purpose (MP).

#### **References:**

- 1. Arlon LLC http://www.arlon-thermal.com/ about/
- 2. Laird Technologies http://www. lairdtech.com/WorkArea/DownloadAsset. aspx?id=5046
- 3. Rogers Corporation http://blog. rogerscorp.com/2011/08/12/modeling-apcb%E2%80%99s-thermal-behavior/

- 4. Rogers Corporation http://www. rogerscorp.com/acm/products/28/ RT-duroid-6035HTC-High-Frequency-Laminates.aspx
- 5. Bergquist.com http://www.directindustry. com/prod/bergquist-company/thermallyconductive-substrate-printed-circuitboards-pcb-12681-259344.html
- 6. Engineersedge.com http://www. engineersedge.com/materials-chemicalsadhesives/potting-compounds.htm
- 7. Pottingsolutions.com http://www. pottingsolutions.com/my%20site/ Technology/potting\_hints.htm
- 8. Masterbond, http://www.masterbond.com/ techtips/long-potworking-life-combinedlow-exotherm
- 9. Epoxyset, http://www.epoxyset.com/#
- 10. Epoxies, Etc., http://www.epoxies.com/ video-50-3150FR.htm
- 11. MH&W Inc., http://www.mhw-intl.com/ assets/sealCmpd\_GF300\_GF1000.pdf
- 12. Arctic Silver, http://www.arcticsilver. com/as5.htm

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