# Developments for Copper-Graphite CTE-Matched Thermal Cores for High-Reliability GaN Systems

David L. Saums*, Principal, DS&A LLC,
Chestnut Innovation Center, 11 Chestnut Street,
Amesbury MA 01913 USA

Robert A. Hay, Senior Research Engineer, Parker Hannifin Corporation, North Haven CT
USA

* *Speaker and Corresponding Author Email: dsaums@dsa-thermal.com*

## Summary

Efficient transfer of heat loads from semiconductor devices that must dissipate heat directly into organic printed circuit boards is challenging in applications which require high levels of reliability, especially when exposed to challenging ambient conditions. System designs where only conduction cooling is available, combined with continued miniaturization of devices and increasing device output performance, are even more challenging in harsh environments. For military, aerospace, and similar applications where high-performance radio frequency (RF) semiconductors are to be directly attached to an organic circuit card with solders or other high thermal conductivity joining materials, forced convection may not be available to handle increased heat loads When gallium nitride (GaN) or silicon carbide (SiC) devices are to be designed into such an application with greater heat flux and higher operating temperature capabilities, development of practical conductive core materials for use within the circuit card becomes increasingly important. One or more heavy copper layers have traditionally been utilized to solve this design problem.

Copper has a relatively high coefficient of thermal expansion and temperature-induced stress must therefore be considered within such a circuit card and in selection of joining materials for device mounting. These types of thermal enhancements to circuit cards add weight, a severe disadvantage in aerospace, military, and manpack electronic systems.

Recent developments with copper-graphite composites and a newly-developed manufacturing process that has been used to produce very thin sheet forms with consistent thickness and of a size appropriate for printed circuit card manufacturing requirements are described. These composite materials are intended to replace one or more heavy copper layers within a circuit card, reducing weight, and providing a new design solution available for these difficult problems. The development of a multilayer printed circuit board (PCB) with an integral thermal core manufactured from such a composite yields a critically important advantage: the ability to lower the thermal core CTE value to more closely align with the CTE value of the silicon, GaN, or SiC device which must be soldered or joined to the PCB structure. Development of thermal core materials offering matched CTE values and high thermal conductivity throughout the core in X-Y and Z orientations reduces the potential for temperature-induced stresses and resulting damage in operation.

Such a thermal core material must also be manufactured in specific sheet sizes to match existing standardized PCB manufacturing equipment and processes. This has been a major challenge with very thin sheets of composites. Other application and production requirements are also described. Flight testing for overall PCB thermal performance is underway currently at a major aerospace and defence contractor in a variety of printed circuit cards manufactured with this copper-graphite composite in required formats. Continued development of the manufacturing process may yield materials which are practical for high-reliability commercial electronics systems as cost is reduced.

This presentation will describe the manufacturing process developments that have yielded a CTE-matched highly thermally conductive composite core material available in very thin (0.040” to 0.010” thicknesses) sheet forms sized for drop-in-place use in existing organic PCB manufacturing processes, per IPC standards, in place of heavy copper planes.

Examples of potential applications will also be described for these materials, along with the PCB manufacturing criteria which have been met in order for this to become a commercialized, practical addition to the available CTE-matched materials for high-reliability, harsh environment applications.

This development program was undertaken with support from Lockheed Martin, TTM Technologies, and Naval Surface Weapons Center. Assistance in preparing testing and data collection has been provided by Al Pergande, Staff Engineer, Lockheed Martin; Janice Rock, Research Engineer, US Army AMRDEC (Redstone Arsenal AL USA); John Vesce, Vice President, TTM Technologies; and Ross Wilcoxon.

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[2] Stablcor® is a registered mark of Stablcor technology Inc., Huntington Beach CA USA (www.stablcor.com).

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