Vol. 52 • No. 10
October 2009

Microwave Journal

www.mwjournal.com

Government and Military Electronics

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Low Density Laminate Overcomes PTFE Limitations

Executive Interview Series

MWJ speaks with Jim Carroll, Director of Marketing, Rogers Corp.

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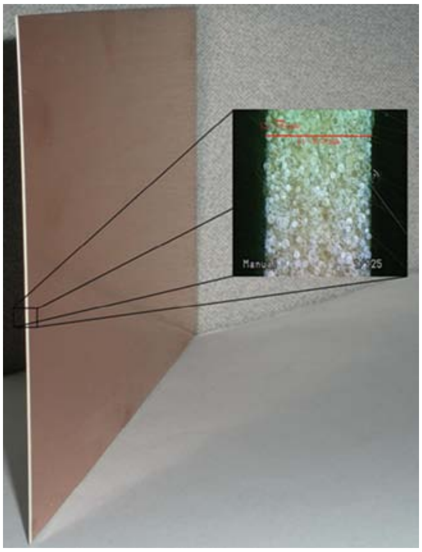
Circuit weight and density are critical factors in some microwave applications, notably in satellites and airborne systems, including unmanned aerial vehicles (UAV). To meet the needs for high electrical performance with mechanical reliability, Rogers Corp. has developed a new addition to its well-known line of RT/duroid® circuit-board materials: RT/duroid 5880LZ laminate. With extremely low density and a dielectric constant of only 1.96 at 10 GHz, it supports the design of lightweight circuits with excellent thermal stability at microwave and millimeter-wave frequencies.



▲ *Fig. 1 Close-up photo of cross section of the 5880LZ laminate.*

RT/duroid 5880LZ laminate has been formulated to overcome the mechanical and electrical limitations of standard PTFE-based laminate materials. The filled composite material offers the lowest dielectric constant in the industry for a copper-clad PTFE-based laminate, with low density of 1.37 g/cm^3 that makes it suitable for applications requiring lightweight circuit boards. The material uses a unique glass filler system that ensures low density and homogenous electrical characteristics unlike similar materials. ***Figure 1*** shows a cross sectional view of the laminate material.

These laminates maintain their low dielectric constant of 1.96 across a board and from panel to panel with a typical tolerance of ±0.04. That low dielectric constant enables designers to take advantage of thinner circuit boards at higher frequencies without paying a penalty in signal losses. Typically, as the operating frequency of a circuit increases, thinner laminates must be used to avoid unwanted spurious propagation. Unfortunately, thinner laminates dictate the use of narrower conductor widths in order to maintain a controlled impedance (typically 50 Ω). Narrower conductors exhibit higher circuit losses; with thinner laminate materials, the losses of the narrow conductors often dominate a high-frequency design. But by using RT/duroid 5880LZ laminate, microstrip and stripline circuits can be

Rogers Corp.
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designed for higher frequencies with thinner substrates while still achieving controlled circuit impedance by means of thicker-than-standard conductor widths. The end result is lower conductor losses at higher frequencies with RT/duroid 5880LZ laminate.

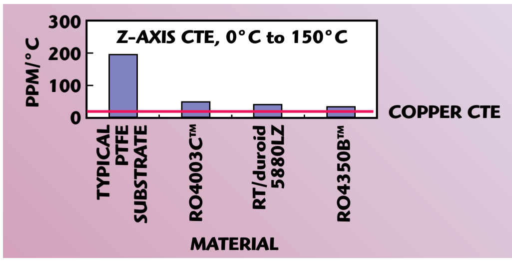
The low dielectric constant of the RT/duroid 5880LZ laminate is beneficial to antenna designers, since the material supports the use of wider conductors at higher frequencies. Since microstrip transmission lines suffer less radiation losses with wider conductors fabricated on low-dielectric-constant materials, antenna efficiency can be increased compared to the use of PTFE-based laminates with higher dielectric-constant values. The RT/duroid 5880LZ laminate exhibits extremely low loss in antenna and other applications, with a typical dissipation factor of 0.0019 at 10 GHz.

THERMAL STABILITY

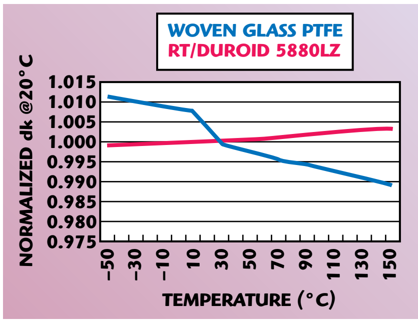
Although PTFE-based substrates have long been used in critical applications requiring the highest electrical performance, designers have had to overcome limitations with PTFE-based materials in terms of thermal stability. Compared to standard PTFE-based substrates, RT/duroid 5880LZ laminate exhibits very little dimensional instability as a function of changes in temperature (see ***Figure 2***). The RT/duroid 5880LZ laminate even performs well in terms of coefficient of thermal expansion (CTE) performance alongside specially engineered non-PTFE materials from Rogers, such as the RO4350B™ and RO4003C™ laminates. Both are ceramic-filled thermoset materials with somewhat higher dielectric constants (3.48 and 3.38, respectively, reinforced with woven glass for dimensional stability).

While the typical CTE for a standard PTFE-based substrate is greater than 200 ppm/°C in the material's z-axis, the CTE for RT/duroid 5880LZ laminate is only 42 ppm/°C. This level of dimensional stability over temperature for the RT/duroid 5880LZ laminate material makes it ideal for multilayer circuits in which layers are electrically connected by means of plated through holes (PTH) and excessive expansion and contraction of the circuit boards can result in PTH reliability issues. When using substrates with poor thermal stability, the integrity of PTHs can be compromised when multilayer designs are subjected to thermal cycling during manufacturing test.

In terms of manufacturing, some PTFE substrates with higher CTE values suffer from reliability problems when used in lead-free manufacturing processes. The RT/duroid 5880LZ laminate, with its low CTE, can be routinely processed by means of lead-free manufacturing approaches without concern for reliability.



▲ *Fig. 2 CTE performance comparison of different laminate materials.*



▲ *Fig. 3 Comparison of the thermal coefficient of dielectric constant for 5880LZ laminate and woven glass PTFE materials.*

In comparing the thermal characteristics of different circuit-board materials, CTE is often used to evaluate the suitability of a material for multilayer circuit applications. In addition to the physical contraction and expansion with changes in temperature, a substrate's dielectric constant will also vary with temperature, according to a parameter known as the thermal coefficient of dielectric constant. For many materials, this value can be quite high, indicating large changes in dielectric constant as a function with large changes in temperature. For an antenna, for example, a large change from the designed dielectric constant value can result in an unwanted shift in the operating frequency. Typical PTFE-based laminates may exhibit a thermal coefficient of dielectric constant of +150 ppm/°C or higher; the 5880LZ laminate offers a well-controlled thermal coefficient of dielectric constant of +22 ppm/°C. By maintaining stable dielectric constant with temperature, the impedance of the transmission lines and, therefore, the performance of the overall circuit and system, remain stable over variations in temperature. As a comparison, ***Figure 3*** shows the thermal coefficient of dielectric constant for the 5880LZ laminate versus a woven-glass-reinforced PTFE-based substrate.

Unlike traditional PTFE-based substrate materials, the RT/duroid 5880LZ laminate does not rely on woven-glass reinforcement for dimensional stability but employs a unique filler system to achieve dimensional stability over time and temperature in a low-density substrate material. In some circuit substrate materials, a woven glass structure is used to improve the dimensional stability of the laminate over time and with changes in temperature. Unfortunately, it can also compromise electrical performance at higher frequencies. The glass structure or cloth suffers from inconsistently located glass bundles throughout a substrate panel, as well as areas known as "knuckles" where glass bundles intersect from one axis (x, y, z) in the substrate material to another. The increased amount of glass in these knuckle areas compared to other locations in the glass structure can adversely affect the consistency and repeatability of the dielectric constant across the laminate, impacting the consistency of electrical performance at higher frequencies. The RT/duroid 5880LZ laminate avoids the use of the glass-reinforced layer and its inherent performance issues through the use of a unique filler system.

The high performance and low density RT/duroid 5880LZ laminate makes it ideal for any application where the weight of the printed-circuit board is an issue. The density of the RT/duroid 5880LZ laminate is only 1.37 g/cm^3 compared to the 2.20 g/cm^3 of most typical PTFE-based substrates, making it ideal for use in satellite payloads and in high-frequency airborne circuitry.

**RT/duroid, RO4350B and RO4003C are licensed trademarks of Rogers Corp.*

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