empfasis

A publication of the National Electronics Manufacturing Center of Excellence *March 2010*

ISO 9001:2008 Certified

Michael D. Frederickson,
EMPF Director

Barry Thaler, Ph.D. • bthaler@aciusa.org
EMPF Technical Director
Empfasis Technical Editor

Paul Bratt • pbratt@aciusa.org
Empfasis Editor

In this Issue

ACI Technologies, Inc.
One International Plaza, Suite 600
Philadelphia, PA 19113
610.362.1200 • *fax:* 610.362.1290
Helpline: 610.362.1320
web: www.empf.org • www.aciusa.org

Properties of Low Dielectric Constant Laminates

There are several attributes to be aware of when regarding high frequency laminate materials which have low dielectric constant (Dk). Several key attributes and how they relate to reliability, manufacturability and good predictable electrical performance will be discussed.

Rogers Corporation is a circuit materials supplier for the high frequency printed circuit board (PCB) industry. With an extensive line of products, the RT/duroid® product line has been used in a wide-range of applications for many decades. Of these products, the RT/duroid 5000 family of high performance laminates offers low Dk laminates with very low Df (dissipation factor). A recent addition, RT/duroid 5880LZ laminate, has the lowest Dk and offers several improvements to most other PTFE (polytetrafluoroethylene) laminates.

PTFE based substrates are used to provide a laminate with a Dk that is relatively low (<2.5 for example). While PTFE has very good electrical properties, other properties need to be well understood for several considerations. The impact of CTE (Coefficient of Thermal Expansion), TCDk (Thermal Coefficient of Dielectric Constant), low modulus, and non-wettability will be discussed.

The RT/duroid 5870 and 5880 are low loss laminates that have been in use for decades. While both have a relatively high percentage of PTFE, the addition of a small amount of filler and some special processing reduces the x-y axis CTE to the range of 40 ppm/ºC (from the 300 ppm/ºC of pure PTFE). Keeping the x-y axis CTE relatively low and near the CTE of copper (17 ppm/ºC) is beneficial for reliability. Even though the CTE is higher in the z-axis (thickness) direction (173ppm/ºC and 237ppm/ºC for the 5870 and 5880, respectively), these materials have been used in numerous high reliability applications for many years. In general, a simpler PCB construction, such as a microstrip, minimizes reliability concerns. If the PCB construction is also thin, the effects of CTE can be made negligible. Also, multilayer applications have used this material successfully when certain considerations are met. Again, keeping the material thinner is beneficial and making a hybrid construction using very low CTE materials with

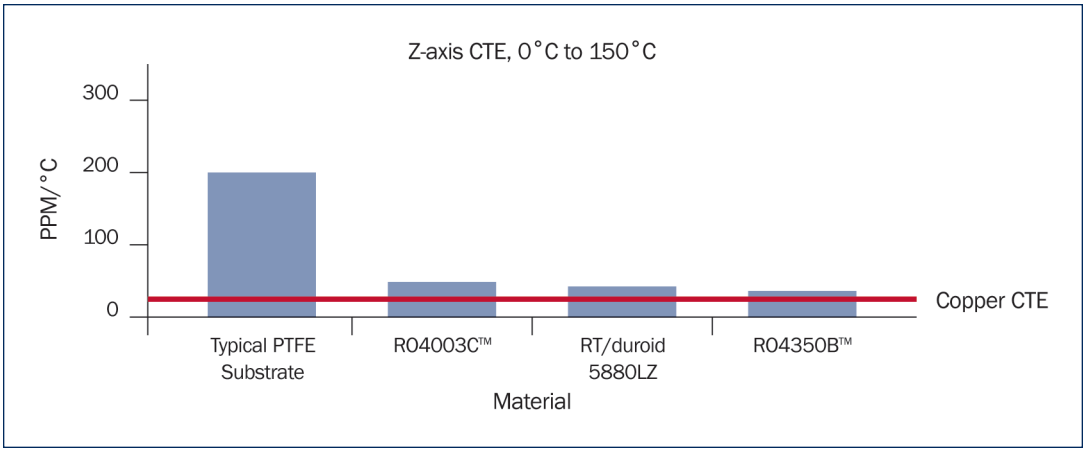

Figure 1-1: Comparisons of different high frequency laminates.

continued on page 7

Properties of Low Dielectric Constant Laminates

(continued from page 1)

the RT/duroid 5000 laminate will minimize any reliability concerns. Often, the circuit design will use RT/duroid material for the critical electrical layers and then use lower CTE materials for the other layers.

These materials have some of the lowest values for Dk and Df in the market. When tested at 10GHz, the Dk of RT/duroid 5870 and 5880 is 2.33 and 2.20 and the Df is 0.0012 and 0.0009, respectively.

The RT/duroid 5880LZ laminate has several other benefits to offer. Besides a very low Dk of 1.96 and a Df of 0.0019, special filler technology makes the CTE of this material approximately 42 ppm/ºC for all three axes.

A comparison of different laminates used in the high frequency industry are shown in Figure 1-1.

A topic that is often overlooked is the TCDk of the substrate. The thermal coefficient of dielectric constant is a property which is inherent in all PCB materials. Many times this property is not well considered in the design phase, which can be adversely realized in the end-user phase of a project. The changes in dielectric constant with temperature can be very significant for many high frequency materials. Most PTFE materials have a relatively high TCDk, or in other words, the dielectric constant will change more with a change in temperature. In some applications this will be more obvious than others. Many typical PTFE substrates will have a TCDk which is 150 ppm/ºC or greater. The RT/duroid 5870 and 5880 are lower than this value; however the 5880LZ substrate has a very good TCDk of 22 ppm/ºC. Basically, when the 5880LZ material is used in an application where the PCB can be exposed to a wide range of temperatures, the dielectric constant will remain much more stable than nearly all PCB laminates. Of course a stable dielectric constant across a range of temperatures will yield stable circuit impedance and a much more stable system performance. A comparison of the TCDk for the 5880LZ laminate and a woven glass PTFE substrate is shown in Figure 1-2.

The control of the Dk value as the material is manufactured is critical, so the end user will have consistent electrical performance. The RT/duroid 5870 and 5880 have their Dk values held to a tolerance of ± 0.02 and the RT/duroid 5880LZ is ± 0.04 as reported by the industry standard IPC test method IPC-TM-650 2.5.5.5c.

The density of RT/duroid 5880LZ is significantly less than any traditional high frequency laminate, which translates to a much lighter PCB. The density of most PTFE substrates is about 2.20 gm/cm^3 while the 5880LZ laminate is 1.37 gm/cm^3. This considerable reduction in density will yield much lower payload or airborne weight as it relates to the high frequency PCB. This is a great benefit for airborne or space deployed applications.

There are several PCB manufacturing issues for any laminate and PTFE laminates are no exception. Since these laminates have been in use for many years, the fabrication issues are well understood. The main issues for circuit fabrication are: drilling, plated through hole (PTH) preparation and plating, softness of the material, and dimensional stability. Very specific PCB fabrication guidelines for RT/duroid materials are provided on the Rogers Corporation website.[1] In general, to address these issues:

1. The main consideration for hole drilling is to minimize heating the substrate to prevent smear.

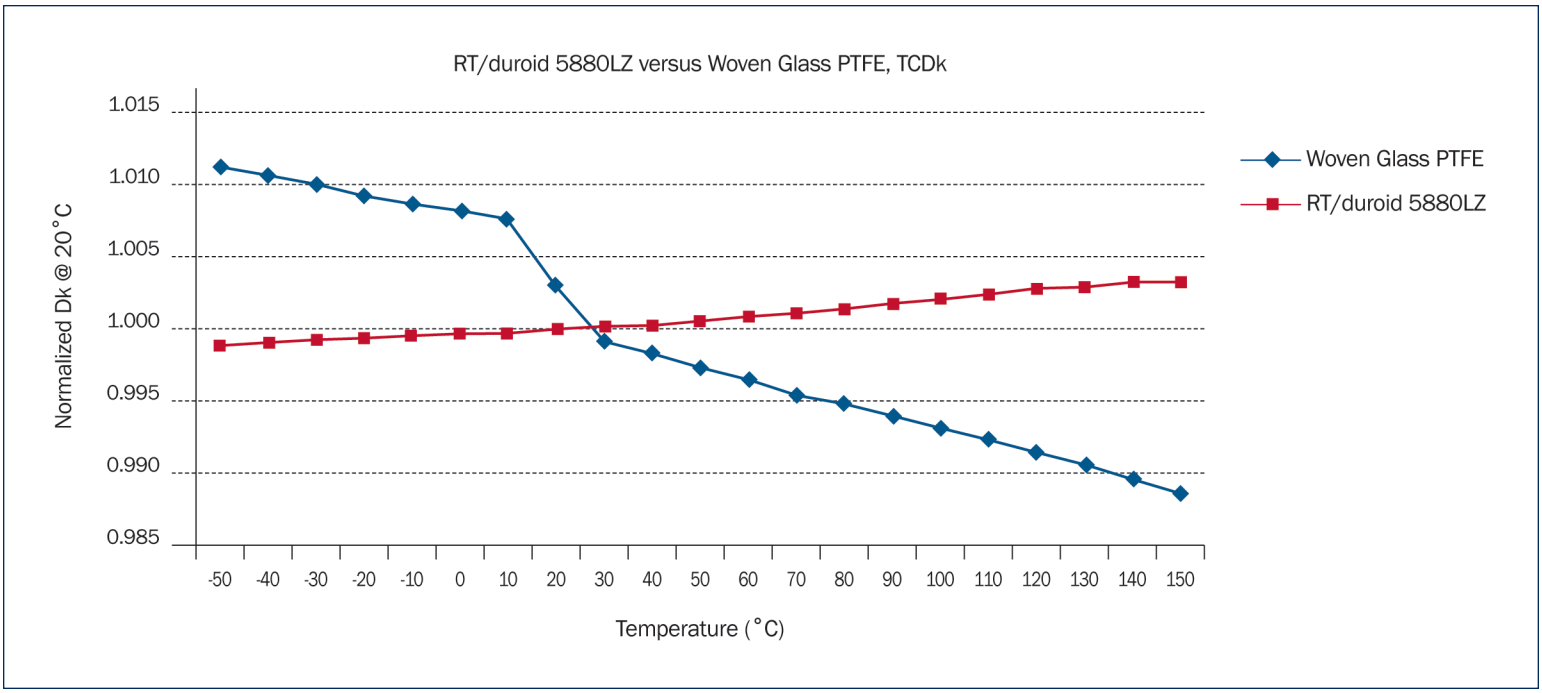

Figure 1-2: PTCDk comparison between a woven glass PTFE laminate and RT/duroid 5880LZ.

continued on page 8

Properties of Low Dielectric Constant Laminates

(continued from page 7)

2. To allow the liquid processing that will deposit copper on the wall of the drill hole for PTH, the PTFE material must be made wettable by removing a fluorine molecule. The removal can be done by a wet process using sodium naphthalene or by a special plasma process. For a nearly pure PTFE substrate, the wet process will generally have better results.
3. The softness of the material will translate into process handling and sometimes dimensional stability issues. This material should not be scrubbed or mechanically stressed during the PCB fabrication process.

The RT/duroid family of products offers several laminates with a low Dk. The RT/duroid 5000 family of products has the lowest Dk values on the market today as well as stringent control of this property. The CTE issue associated with PTFE based laminates can be overcome by the use of a thinner laminate and multilayers using hybrid constructions. Also, with the introduction of the 5880LZ laminate, the CTE is in the range where high reliability for PTH is expected. The TCDk issue is sometimes overlooked and can be an issue for some laminates and applications. The 5880LZ has a very low TCDk, enabling it to be used in temperature varying applications predictably. Lastly, the low density of the 5880LZ can be very beneficial to applications where weight is restricted.

For more information about these or other high-frequency laminates suitable for your design, contact Mr. John Coonrod with Rogers Corporation, at 480.961.8398, or via email at john.coonrod@rogerscorp.com.

1 *RT/duroid® 5870/5880/5880LZ High Frequency Laminates*. Rogers Corporation, 2009. Web. 27 Jan. 2010. <http://www.rogerscorp.com/acm/products/10/TR-duroid-5870-5880-5880LZ-High-Frequency-Laminates.aspx>.