"Tech Talk for Techies" #4

Beyond FR-4: High Performance Materials for Advanced Designs

Part One of Two

THE EVOLUTION OF FR-4

In the past forty-plus years of printed circuit board (PCB) manufacturing, the primary material of choice has overwhelmingly been e-glass supported FR-4 resin laminates. This is due to the excellent dimensional stability and reasonably acceptable thermal performance (based on glass transition temperature Tg and decomposition temperature Td). In general, these materials exhibit impressive performance and excellent cost for a wide range of applications.

Cheaper and lower performance materials such as the CEM class and earlier G10 and FR-5 formulations have largely disappeared and are no longer used in mainstream products. There are still very low-cost foreign die-cut low-tech laminates used for very inexpensive and simple circuits but again have largely been replaced by the competitive price and superior performance of modern FR-4 materials.

Now as the circuit board has become an integral part of the signal path with controlled impedance and specific transmission line performance specifications necessary for the design, higher performance materials have emerged in the FR-4 category to meet the need. High speed designs requiring lower dielectric constant (Dk) and lower loss tangent have driven materials R&D to provide advanced FR-4 laminates such as Panasonic Megtron 6, Isola FR408, Nelco N4000-13, and even e-glass engineered to lower the Dk such as Nelco's SI (for signal integrity) cloth. More and more modern designs are moving to these higher speed FR-4 offerings.

But there are applications that demand even greater thermal performance and severe environment reliability that requires materials with specific qualities not present in these modern FR-4 laminates. And some of these materials have been with the industry for decades but never found a wider audience due to limited supply and/or higher cost.

POLYIMIDE

This legacy material has been with us for decades and continues to provide a solution for designs requiring increased thermal performance, higher operating temperatures, and severe environment capability. Compared to FR-4's glass transition temperature typically in the 170C to 180C range (typical FR-4 chosen for medium to advanced designs), Polyimide's Tg is in the 260C area. The decomposition temperature is well over 400C (lead-free assembly requires a typical 340C or greater), and the maximum operating temperature (MOT) as tested/certified by Underwriters Laboratories (UL) is in the 140C to 210C range (short and long term testing qualification). This is much greater than the MOT of FR-4 which is typically 130C.

There are a couple of technical issues to be aware of when selecting Polyimide—the first being which chemistry formulation to use. Most Polyimide laminates and prepregs are available in Brominated and Non-Brominated blends (the flame retardant which is also used in FR-4). Non-MDA (Methylenedianiline) formulations also tend to be less brittle. One issue to watch is the moisture absorption characteristics as Polyimide can exhibit higher leakage as compared to FR-4 resin systems. Overall, it is best to compare your design requirements carefully in all areas to be sure that Polyimide will provide the necessary benefits without undue negative performance issues.

PPO/PPE

For many years Getek has been a choice for designers requiring a material with superior characteristics for higher speed designs. The PPO (Polyphenylene Oxide) epoxy resin is the closest to FR-4, but exhibits a lower Dk (3.60) and Df (0.009) in an affordable material that is supported by most PCB fabrication shops due to standard manufacturing specifications. However, in recent years the supply has been reduced as it remains a material not quite in the mainstream, so suppliers now manufacture it on an as-ordered basis resulting in typically longer lead times.

A newer material to excite the industry in the past few years, and one that is rapidly increasing its market share is Panasonic's Megtron 6, which comes in a PPO (as well as PPE) blend. The superior performance is due to very low Dk and Df so it is a natural candidate for high-speed designs. The tradeoff is that it is a Japanese-manufactured material so domestic USA stocking and local availability can vary accordingly.

HIGH FREQUENCY/RF MATERIALS (Hydrocarbon/Ceramic, PTFE, etc.)

Both Rogers Corporation and Taconic offer several flavors of materials engineered to address the needs of the high frequency, microwave & RF world. These are specific laminates, often requiring different types of b-stage/prepreg or bonding sheets to laminate them for multilayer designs.

By far the most commonly used is the Rogers RO4000 series of high frequency materials. RO4350B laminate is a hydrocarbon/ceramic base, which can be manufactured using standard FR-4 type multilayer processes, making it not only popular but economical to manufacture. Low dielectric loss is the major appealing characteristic of this material. Multilayers can be constructed of a "pure package" using Rogers 4450 prepreg, or by using standard FR-4 prepreg. Popular constructions limit the Rogers material to the "caps" of the stackup thereby managing overall cost by using the material only where it is required, and filling the remainder of the board with standard FR-4 cores/prepreg.

PTFE, commonly known as "Teflon" is another fairly common callout for this genre's material requirements. There are many different formulations and laminates such as Rogers 3000 series ceramic-filled PTFE composites, R/T Duroid 5870 and 5880 glass microfiber reinforced PTFE, etc. They can be very difficult in multilayer configurations however, as some require the use of high temperature bonding films or adhesives. The old saying that "nothing likes to stick to Teflon!" sometimes holds true! But their extremely low loss characteristics make them ideal for exacting stripline and microstrip circuit designs.

NEXT GENERATION LAMINATES & MATERIALS

In keeping with a concise paper length for the Tech Talk column there are a multitude of materials and laminates that are used in today's modern PCB designs that we do not have the space to cover in this installment. So although we have run out of room this time we will continue our examination of these materials in our next Tech Talk—Part Two, beginning with next generation materials. This is an exciting time in PCB history and we invite you to join us with Part Two in the weeks to come.

As always, for more information please do not hesitate to contact your Advanced Circuits representative to obtain more in-depth information on the materials we presented today!