

# THE pcb DESIGN MAGAZINE

April 2014

AN  I-CONNECT  PUBLICATION

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# Hybrid High-Frequency Multilayer PCBs

by John Coonrod  
ROGERS CORPORATION

A hybrid multilayer PCB uses materials with significantly different critical properties than those associated with a traditional multilayer PCB. A hybrid could use a mix of FR-4 materials with high-frequency materials, or a mix of different high-frequency materials with different dielectric constants. Hybrid construction is becoming more popular as technology evolves, but they bring with them some benefits and challenges which need to be better understood.

The reasons for using a hybrid multilayer PCB typically fall into one of three categories: cost, improved reliability, or enhanced electrical performance. High-frequency circuit materials are typically more expensive than FR-4 types. Sometimes, hybrids using a combination of these two different materials are constructed to ease cost issues. Many times, a multilayer PCB will feature some circuit layers that are electrically critical and many layers that are not critical. In this case, the less expensive FR-4 material is used in the non-electrically-critical layers and the more expensive high-frequency material is used in the more critical layers.

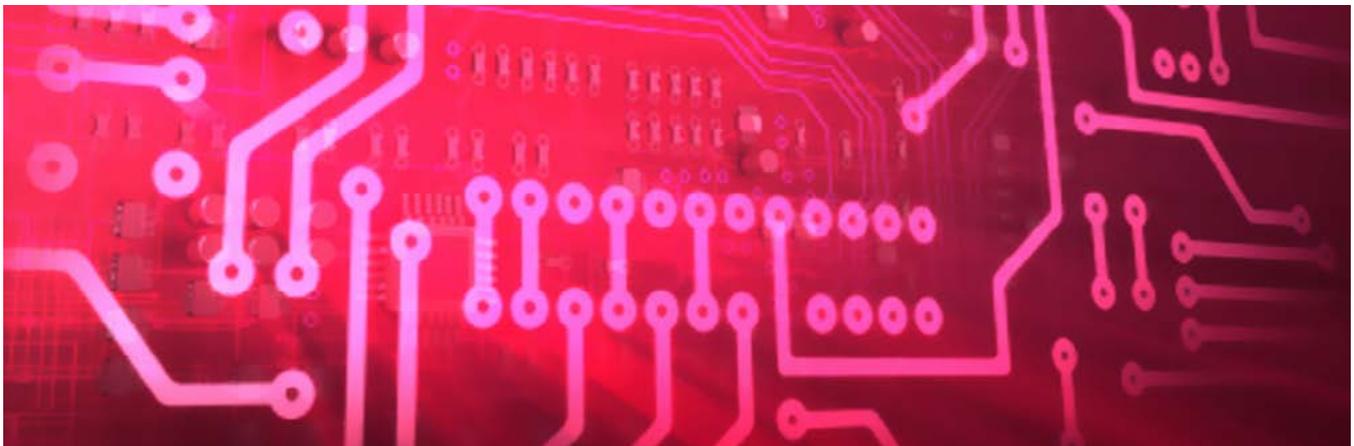
Another reason for using hybrid multilayers is to improve reliability when one of these materials has a high CTE. Some high-frequency

PTFE materials have high CTE properties and that can be a reliability concern. When an FR-4 material with a low CTE is used in conjunction with the high CTE material to make the multilayer, the composite CTE can be acceptable.

Some hybrids use materials with very different dielectric constants that are used for enhanced electrical performance. In the case of some couplers or filters, it may be advantageous to use laminates with different dielectric constant values.

The combination of FR-4 and high-frequency materials is becoming more common since there are few compatibility issues related to using FR-4 and most high-frequency circuit materials. However, there are several circuit fabrication issues which need to be understood.

The type of high-frequency material used in a hybrid construction can make a big difference in the degree of special processing needed for circuit fabrication. PTFE-based high-frequency materials can be more problematic for circuit fabrication due to special drilling and plated through-hole (PTH) preparation requirements. Hydrocarbon-based laminates can easily be fabricated using standard FR-4 circuit board processing techniques.



**HYBRID HIGH-FREQUENCY MULTILAYER PCBS** *continues*

A combination of FR-4 materials and high-frequency hydrocarbon laminates typically has few circuit fabrication issues. The main concern with this combination of materials is typically drilling and lamination. A DOE (design of experiments) is usually necessary to establish the proper feeds/speeds for drilling a circuit of this combination of materials. Lamination can be an issue for FR-4 prepreg, which often requires a ramp rate that is very different than the high-frequency prepreg. In order to make a more reliable hybrid, there are a couple of options to consider when using FR-4 and hydrocarbon prepreg. One option is to replace the FR-4 prepreg with the high-frequency prepreg and use the appropriate lamination cycle. A high-frequency prepreg is typically not as expensive as the laminate, and having all bonding layers made of the same material is beneficial for a simpler lamination cycle. When the FR-4 prepreg cannot be replaced, it may be necessary to do sequential lamination, where the first lamination cycle cures the FR-4 prepreg and the second lamination cycle cures the high-frequency prepreg.

A hybrid multilayer PCB using a combination of FR-4 and high-frequency PTFE circuit materials can be more challenging, however there are some exceptions. There are several different types of PTFE-based laminates and some are easier to fabricate than others. Even though ceramic-filled PTFE-based laminates have less circuit fabrication concerns than a pure PTFE laminate, drilling, PTH preparation and dimensional stability must be considered.

The main concern about PTH drilling is that the PTFE material is relatively soft and the FR-4 material is rigid. When the PTH is drilled and the drill tool goes through the interface of these material boundaries, the hole can have a flap of soft material stretched over some length within the PTH wall. This can be a serious reliability issue and must be addressed. Typically the proper feeds and speeds must be determined through a DOE and a study regarding drill life.

Many times the flap defect does not occur early in the drill tool life, so understanding the drill life is important for minimizing this concern.

The PTH preparation must address both types of materials for the plated through-hole process. The plasma cycle will probably need to be two different cycles or one cycle with multiple stages. The FR-4 materials should be treated in the first plasma cycle and the PTFE materials in the second cycle. Typically, the plasma process for FR-4 uses  $\text{CF}_4\text{-N}_2\text{-O}_2$  gases, and PTFE uses He or  $\text{N}_2\text{H}_2$ . For improved through-hole wall wettability, the recommended cycle using helium (He) is a better choice for treating PTFE. If wet processing is used to prepare the PTH, perform the permanganate first for the FR-4 materials followed by sodium naphthalene to treat the PTFE material.

Dimensional stability or scaling can be an issue with PTFE and FR-4 hybrids. This can be reduced by minimizing mechanical stress of the PTFE laminate. Scrubbing the panel induces random mechanical stresses and is not recommended. A chemical clean process is a better method for preparing the copper for subsequent processing. The thicker PTFE laminates will have less issue with dimensional stability and the woven-glass reinforced PTFE substrates will be more stable as well.

In general, the manufacture of hybrid PCBs with a combination of FR-4 and high-frequency circuit materials has few compatibility issues. But several circuit fabrication concerns need to be addressed. When working on hybrid multilayer builds, it is always recommended that the fabricator consult with the material manufacturer for best results. **PCBDESIGN**

***A high-frequency prepreg is typically not as expensive as the laminate, and having all bonding layers made of the same material is beneficial for a simpler lamination cycle.***



John Coonrod is a market development engineer for Rogers Corporation, Advanced Circuit Materials Division. To reach Coonrod, [click here](#).