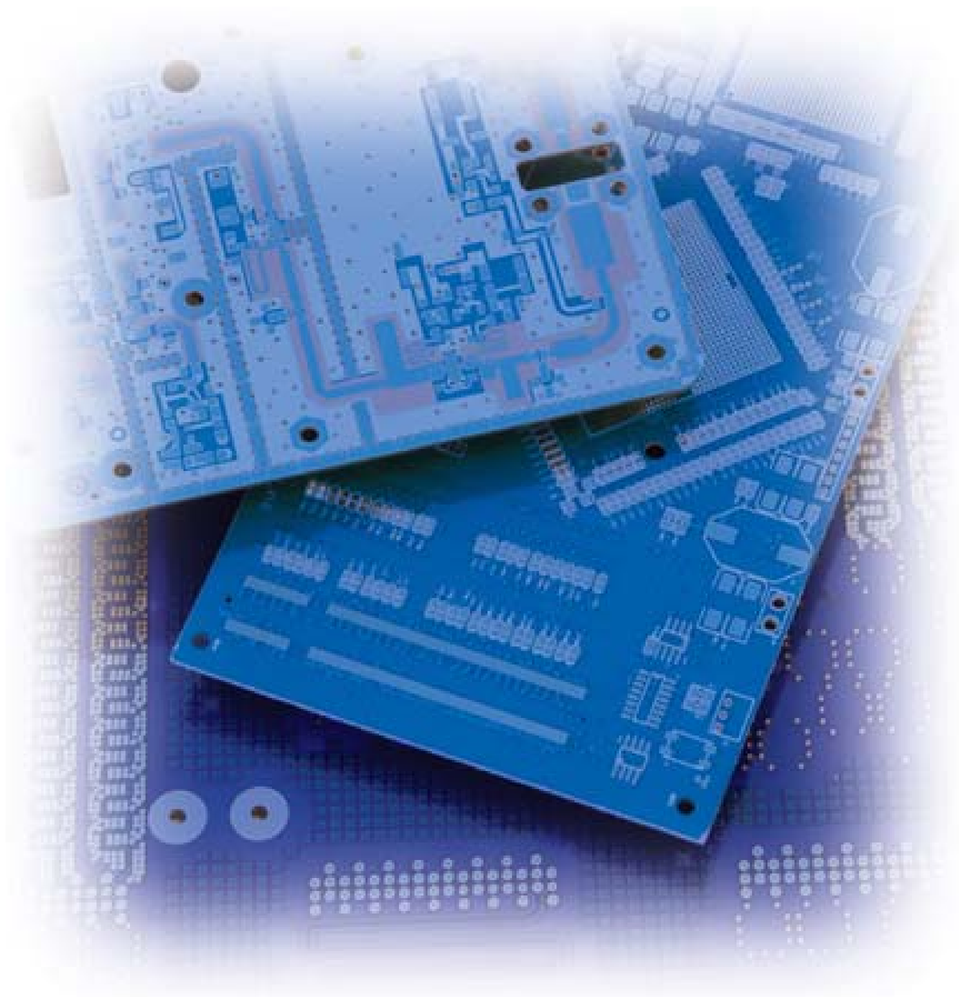
PTFE and Hybrid Multilayer Bonding and Fabrication



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The reasons for selecting circuit board are threefold. First, to allow the integration of digital and Radio Frequency (RF) circuitry into a single assembly. Second, to decrease overall printed circuit board (PCB) size. Third to provide additional thermal paths and increase the rigidity of the final assembly.

There are basically two types of PTFE multilayers. One is an all PTFE substrate multilayer board (MLB) which is typically bonded with a low dielectric constant, low loss sheet adhesive or bonding film. The other is a hybrid or composite multilayer consisting of a layer (or layers) of PTFE and a layer (or layers) of a different material typically FR-4 bonded with a thermosetting prepeg.

Material Selection
The first part of the process is the selection of the PTFE material for the RF signal layer(s). Taconic TLC and TLE materials were specifically designed for multilayer applications. Their combination of low loss (<0.003 @ 10 GHz) and low coefficient of thermal expansion (CTE) in the Z-axis (50-70 ppm/ºC 25-250°C) make them well suited to 4-10 layer multilayers. Taconic TLY and TLX materials are often used in multilayer applications due to their extremely low loss (<0.001 and <0.002 @ 10 GHz respectively) but layer count is typically limited to a maximum of 4 layers due to the higher coefficient of thermal expansion in the Z-axis (280ppm/ºC and 140ppm ºC 25-250ºC respectively).

Artwork Sizing and Compensation
Woven glass reinforced PTFE laminates will have positive dimensional change in the X and Y axis after removing most of the surface copper to produce a circuit layer. This growth can be compensated for by shrinking the inner layer artwork prior to imaging. Exact values depend on the amount of copper removed from a layer, circuit pattern and layer thickness. Figure #1 offers some basic scale factor values for the different material types.

Laminate	Positive Dimensional Change in Parts Per Million (PPM)
TLC	200-400
TLE	220-400
TLT	400-600
TLX	400-600
TLY	400-800

Figure 1

Innerlayer Preclean, Dry Film Lamination and Imaging

Preclean
As with thin core or flexible substrates mechanical scrubbing or machine scrubbing should be avoided. These processes will stretch or deform the material as it passes through the pinch rollers and rotary scrub brush Chemical preclean should be used exclusively on PTFE laminates prior to dry film lamination.

Lamination and Imaging
Laminate, image and develop per standart innerlayer procedures. Follow manufactures directions for lamination, exposure and development.

Innerlayer Preparation
To ensure a surface that is readily bondable, care should be taken to avoid disturbance of the PTFE surface after removing copper during etching. To provide a suitable finish on the copper surfaces proper cleaning and preparation should be performed. Examples of some surface finishes that have been used

successfully are a light brown oxide, microtech and electroless nickel followed by an immersion of gold.

While it is true oxide coatings and untreated copper surfaces will decompose and oxidize during lamination at temperatures suitable for Fluorinated Ethylene Propylene (FEP) film adhesives, the thermoplastic bond achieved should still exceed IPC specifications.

Thermoplastic Sheet Adhesive/Bonding Films
Typical bonding film materials are FEP and HT 1.5 based film. Figure #2 illustrates their performance at 1 MHz and 10 MHz and recommended bonding temperature.

Typical Properties of Thermoplastic Bonding Films		
Bond Film	FEP	HT 1.5
Dielectric Constant	2.00 @ 1 MHz	2.35 @ 10 GHz
Dissipation Factor	0.0007 @ 1 MHz	0.0025 @ 10 GHz
Recommended Bonding Temperature	282 - 296 ºC 540 - 565 ºF	218 - 232 ºC 425 - 450 ºF

Figure 2

Thermoplastic Sheet/Bonding Film Lamination
Due to the temperature required to melt thermoplastic bond films and sheet adhesives they are not well suited for use in hybrid multilayers where FR-4 or other similar thermosetting materials are used as dielectric layers. The lower thermal degradation point of thermosetting materials will cause them to oxidize and decompose.

Typical lamination pressures range from 100 - 200 PSI at temperature. Adequate press padding should be used to allow for even distribution of pressure. This should yield a uniform bond line thickness and adequate adhesion.

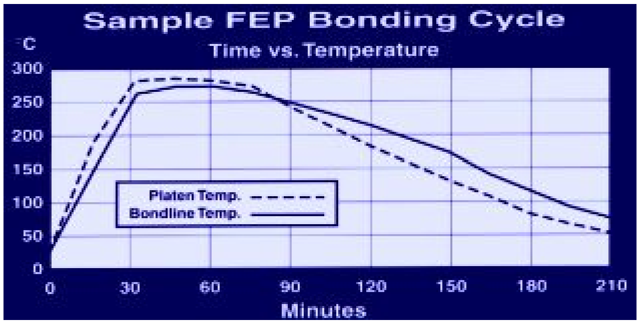

Figure 3

Please note that a high rate of cool down may cause excessive layer to layer stress which may result in delamination. Adequate thermal lagging/padding and a controlled cooling rate should insure a successful bond.

Thermosetting Prepeg Lamination
Hybrid multilayers can be manufactured using conventional FR-4 or similar thermosetting prepeg systems. The lamination cycle, pressure and copper surface preparation should be the same as that used for standard prepegs. Consult the prepeg manufacture for the processing parameters recommended for use with the particular resin system.

Drill Size (mm)	SFPM	Chip Load (mm/rev.)	Feed Rate (mm/sec.)	Speed KRPM
0.45	223	0.0538	43	48.0
0.65	269	0.0628	42	40.1
0.80	305	0.0665	41	37.0
1.20	317	0.0773	33	25.6
1.35	348	0.0768	32	25.0
2.00	412	0.0570	19	20.0
2.35	484	0.0480	16	20.0
3.20	660	0.0450	15	20.0

Figure 4

Post Lamnination Processing

Drilling
Entry material should be a non metallic phenolic coated paper product. Backup phenolic coated hard board material.

Standard FR-4 drill bits with a drill point of 130º will produce acceptable hole quality. Adequate vacuum should be maintained to ensure proper removal of drilling debris to prevent drill wrap or birdnesting of the PTFE material (see drilling equipment manufacturer for recommended vacuum levels).

Hole Preparation for Plating
It is necessary to desmear the through holes of hybrid multilayer PCB´s manufactured with FR-4 prepegs to ensure good mechanical and electrical contact with the innerconnects. This procedure should be performed prior to treatment of the PTFE hole wall surfaces. Desmear does not have to be performed on PTFE multilayers bonded with thermoplastic sheet adhesives, but a plasma treatment or sodium etch is still needed to provide a wetable surface for the plated through hole chemistry.

Plasma Desmear of Hybrid Multilayers
Epoxy resin smear may be removed using standard plasma techniques for FR-4 laminates. Please consult your plasma equipment vendor or FR-4 laminate supplier.

Permanganate or Sulfuric Desmear of Hybrid Multilayers
Chemical desmear may be performed using standard processing techniques for FR-4 laminates. The PTFE will not be effected by either plasma or sulfuric desmear.

PTFE Hole Wall Treatment
A plasma treatment or sodium etch cycle may be used prior to plated through hole (PTH). These treatments modify the PTFE in the trough hole allowing the PTH chemistries to wet out the hole wall surface. This process should be performed after desmear on hybrid multilayer PCB´s. The FR-4 will be unaffected by either process. Please contact your sodium enchant manufacturer for information regarding processing guidelines.
Plasma desmear and PTFE treatment may be performed in consecutive cycles. First, perform the desmear cycle to remove FR-4 resin smear. Second, perform a PTFE treatment cycle to modify the PTFE through hole surfaces. Please note that maximum hold times after plasma treatment may be as short as one hour prior to PTH. The maximum hold time should be arrived at using empirical data.

The following are two plasma cycles which have been used successfully. Please note that all plasma equipment and circuit designs will be different. This factor combined with variations in laminate thickness, resin content and hole diameter make it necessary to experiment with different cycles and anode placements to achieve fool-proof results.

PTFE Plasma Treatment Cycles

Cycle A

Stage 1	O_2 50%. He 50% at 4300 watts Rf and 250 psi for 10 minutes
Stage 2	He 100% at 2575 watts RF and 250 psi for 15 minutes End point temperature is 175ºF

Cycle B

Stage 1	O_2 90%, N_2 10% End point temperature is 75ºC. Use temperature to establish power levels
Stage 2	CF_4 10-15%, 0_2 - balance End point temperature is 110ºC
Stage 3	0_2 100% One half power used in Stage 1

Plated Through Hole

Once the PTFE is treated, the through holes may be metallized using either electroloss copper or direct metalization process. Depending on multilayer complexity and thickness. the finished product should meet all IPC requirements for copper plating thickness and reliability.

Summary

PTFE multilayer circuit boards and hybrid circuit boards may be manufactured both efficiently and consistently using today´s more rigid and reliable PTFE materials. Advances in fabrication and the understanding of woven PTFE products have greatly improved the success when building a PTFE of hybrid multilayer of current high power, high density designs. As with any process, the level of understanding and control are the ultimate factors in determining the success of a material within that process.