Presented in the ECWC 10 Conference at IPC Printed
Circuits Expo®, SMEMA Council APEX® and
Designers Summit 05

The Feasibility of Blind Via on PTFE-FR4 Laminated Multi-Layer PCB

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Abstract
PTFE-FR4 hybrid laminated multi-layer PCB technology is being applied more and more widely. This technology requires blind via fabrication in a PTFE core. This paper gives a picture of the manufacturing process for multi-layer PCBs with PTFE focusing on material specifications of anti-overflow and surface treatment techniques, thereby addresses the feasibility of this technology.

Key words: Laminated multi-layer PCB with blind via

Introduction
For PTFE core and FR4 prepreg mixed multi-layer PCB, designed for its particular mechanical performance, the PTFE fabricating process is very special. For example, it's very difficult to use common mechanical brush to eliminate overflowed resin during surface treating. Except the special requirement for surface treating, overflow resin performance is the key to fabrication.

Analysis of Test Factors
We should pay attention to the reference point for the fabrication of PTFE-FR4 laminated multi-layer PCB. It will be described by the following:

- Shrink-swell compensation: The shrinkage rate of PTFE-FR4 laminated board is more variable than that of common board. Additionally, the shrinkage rate can be measured and easily compensated.
- Impedance calculation: There has been developed a new formula for laminated boards with different dielectric capacity.
- PTH issue: FR4 is raw material of laminated boards, as well as PTFE. The drilling parameters of these two kinds of material are very different. Drilling parameters are calculated based on PTFE specification, but desmear is based on plasma.
- Bonding force between PTFE active surface and FR4: The time internal between etching and laminating should be defined because the active surface of the PTFE core cannot be exposed to the air for a long time. Otherwise the active surface will be affected.

Including the issues mentioned above, the biggest problem is how to clean the overflowed resin. The resin on the copper cannot be wiped out by grinding or brushing. So, we are looking for a non-mechanical method to clean it. This is what we are focusing on.

Experiment Design
This parper focuses on overflow resin treating and resin thickness controling. There are 3 sections to introduce the experiment process: release film selection, overflow resin elimination process and reliability testing.

Test board design: The cores are 2 pieces PTFE (Thickness: 0.254mm), Prepregs are 2 piece 2116 FR4 prepreg. (See Figure 1.)

Figure 1 - Test Board Structure

Release Film Selection (See Table 1.)

Table 1 - Release Film Types and Blind Via Diameter (Unit: mm)

	Blind hole 1	Blind hole 2	Blind hole 3	Blind hole 4	Blind hole 5
Release film A	0.3	0.5	0.7	1.0	1.5
Release film B	0.3	0.5	0.7	1.0	1.5

Note: 0.3mm and 0.5mm is common diameter used for blind via. Other diameters are used for testing filling capability.

Overflow Resin Eliminating Process

Overflow resin was eliminated by micro-etch and chemical desmear. One micro-etch circle can remove 2um copper. The desmear can remove 1-2 um resin. The parameters were adjusted with micro-etch and the desmear to optimize results.

Release Film Test Result

Release film performance is evaluated by the blind hole diameter, by the range of overflow resin, and by the concave depth of resin surface. The less range of overflow resin is, the easier it is to clean the copper surface. The smaller the concave depth is, the better the surface appearance looks. (See Table 2 and 3.)

Table 2 - Test Result

Item	Result description (Release film A)	Result description (Release film B)	Summary
Overflow resin character	Resin flow out from all blind holes. The resin thickness is almost equal. It read between 0-5.6um by cross section measurement.	Resin flow out from some blind holes (about 40%). The width of resin annulus is 0.3mm. The resin thickness is about 2um.	Release film B is better.
Appearance	Resin particles distributed on surface.	Resin particles distributed on surface.	The performance has nothing to do with release film thickness.
Release film after hot press	The film A is thinner and harder than film B. No wrinkle is on the resin surface.	The film B is thicker and softer than film A. There is wrinkle on resin surface	Release film with A is better.

Note: The thickness of release film A is 0.06mm. Film B is 0.127mm.

Table 3 - Surface Concave Obtained over Different Release Film Thickness and Different Diameter (Unit: um)

film thickness	diameter(mm)	data 1	data 2	data 3	data 4	Average	standard deviation
A	0.3	20	20	20	20	20	0
	0.5	20	20	16.7	16.7	18.35	1.90525589
	0.7	21.7	25	28.3	33.3	27.075	4.94797939
	1	28.3	25	21.7	25	25	2.69443872
	1.5	30	31.7	31.7	31.7	31.275	0.85
B	0.3	43.3	45	45	47.5	45.2	1.73012524
	0.5	86.7	80	78.3	78.3	80.825	3.9978119
	0.7	95	96.7	95	95	95.425	0.85
	1	135	106.7	106.7	106.7	113.775	14.15
	1.5	153.3	153.3	140	146.7	148.325	6.36258595

Summary

A. For film A, resin streams out around the orifice. The width of resin annulus is about 0.3mm. And the surface is wrinkled. For film B, resin flows evenly.
B. In stacking operations, resin flow between the release film and board surface leaves an irregular surface on the board.
C. For film B, the infilling capability changes with hole diameter. The larger the orifice diameter is, the worse the infilling capability. The deepest concave is 148.3um.
D. For film A, the infilling capability also changes with hole diameter, Changing from 0.3mm to 1.5mm, the depth of concave offset range is only 1.3um. Additionally, the deepest concave is 31.28um.

Resin Cleaning

We used the chemical desmear ($KMnO_4$) to clean the surface resin on the laminated board. We decided to desmear the boards 2 times because of the resin thickness. The process is to etch 2um, then to clean 2 times by chemical desmear. After that, we still found some brown-oxidation left. So we need to etch 2um again until it becomes clean.

Experimental phenomenon analysis

Figures 2-9 show us there still is some resin after desmear and micro-etch. No defects were found on film after cleaning process. But defects can be found on film B. Further more, the resin around orifice cannot be eliminated.

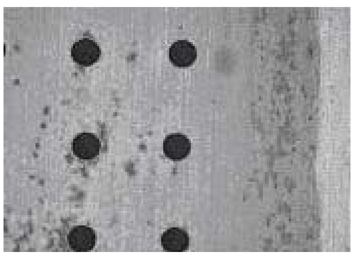

Figure 2 - Desmear 2X（Film B）

Figure 3 - Desmear 2X（Film A）

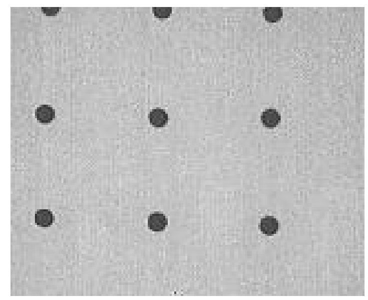

Figure 4 - After Micro-etch (Film B，Φ0.3mm)

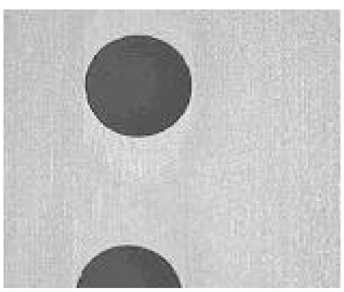

Figure 5 - After micro-etch（Film B, Φ1.5mm）

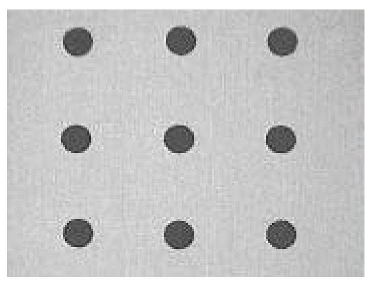

Figure 6 - After Micro-etch (Film A，Φ0.3mm)

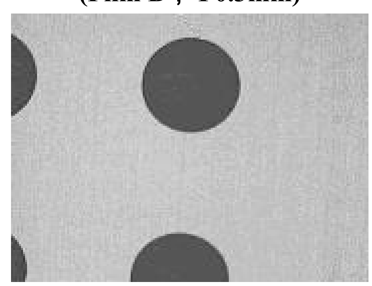

Figure 7 - After Micro-etch (Film A, Φ1.5mm）

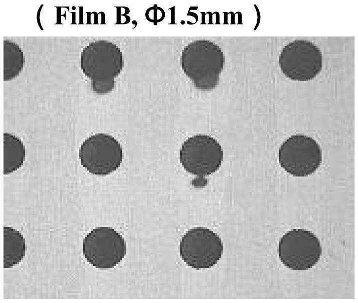

Figure 8 - Disfigurement after Micro-etch（Film B，Φ1.0mm）

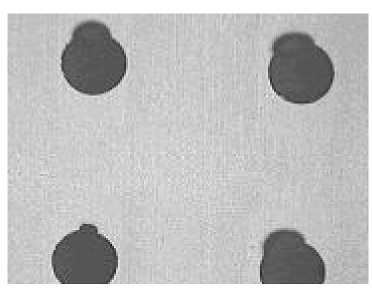

Figure 9 - Disfigurement after Micro-etch（Film B，Φ1.5mm）

Project Improvement

The traces left after etching are the resin trapped in the concave brown-oxidation layer. Because the brown-oxidation layer thickness and roughness are less than 1.0um the brown-oxidation layer and resin can be eliminated by micro-etch an additional time. This indicates that this process (micro-etch twice) is feasible.

For film A, the process flow is as following:

Micro-etch→Desmear one time→ Micro-etch

For film B, the process flow is as following:

Micro-etch→Desmear two times→ Micro-etch

Brown-Oxidation Influence

The influence of oxidation surface should be studied in order to make the process steady-going. Commonly, brown-oxidation is the popular process for internal layer oxidation. We can know what is the brown-oxidation function in the desmear process through comparison of process between brown-oxidation and non-brown-oxidation . Film A was chosen in this test.

We choose brown-oxidation boards and non-brown-oxidation boards. Figures 10-15 are the phenomena after the cleaning process.

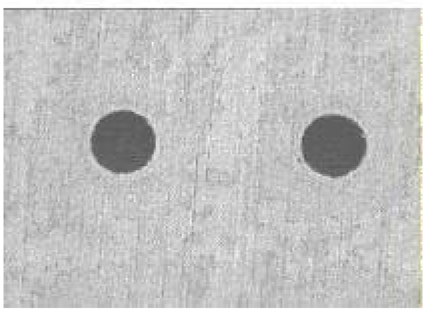

Figure 10 - Brown-Oxidation
(Φ0.3mm, without last micro-etch)

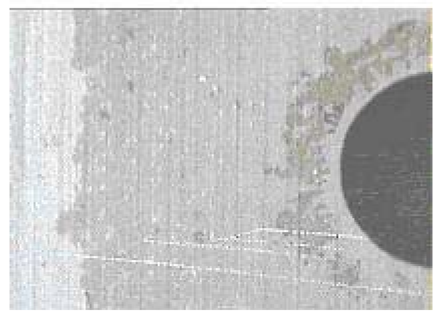

Figure 11 - Brown-Oxidation
(Φ1.5mm, without last micro-etch)

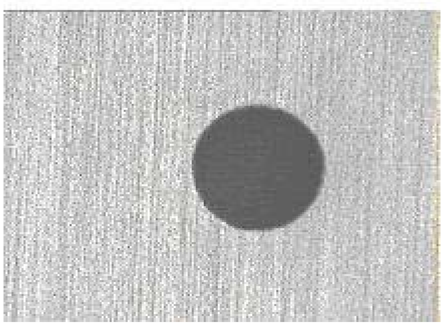

Figure 12 - Brown-Oxidation (Φ1.5mm)

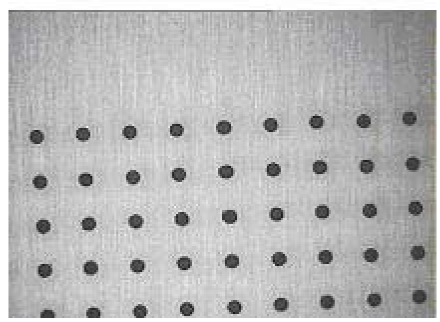

Figure 13 - Brown-Oxidation (Φ0.3mm)

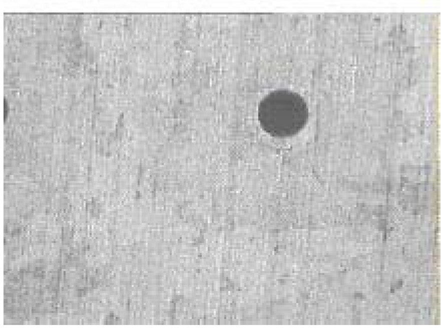

Figure 14 - Non-Brown-Oxidation (Φ0.3mm,)

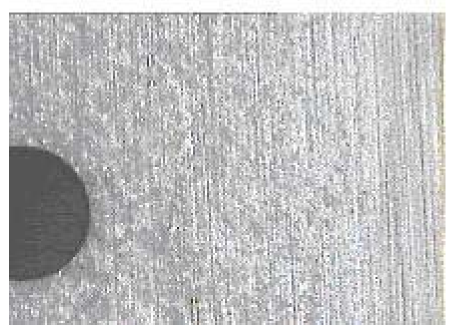

Figure 15 - Non-Brown-Oxidation (Φ1.0mm)

Experiment Summary

a. Without the second micro-etch, resin is found on both brown-oxidation boards and non-brown-oxidation boards.

b. With the second micro-etch, resin on brown-oxidation board can be removed completely. The resin on non-brown-oxidation boards cannot be cleaned. Resin is separated from copper by brown-oxidation layer. It isn't integrated into the surface.. After etching, the brown-oxidation layer is removed by micro-etch liquid that penetrated into the surface roughness that appeared after desmear. The resin is easily striped. The resin on non-brown-oxidation board, however, is stuck on the copper tightly. It is difficult to clean this resin.

Reliability test

Thermal stress test

Blind via board is dipped into tin 10 times with 288℃/10s. No defect was found. Result is shown below. (See Figure 16.)

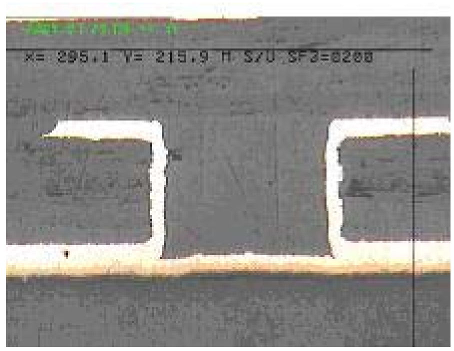

Figure 16 - Section after 10X Thermal Stress

Dipped 15 times, the blind via cross sections are all right.

Aging Test

After one week aging test, no defect was found at cross section and surface.

Re-Flow Process Simulation Test

After 5 re-flow processes, no defects were observed.

Conclusions

In the fabrication of PTFE-FR4 laminated PCB with blind via, the key point is how to control resin thickness and eliminate the resin that overflowed from the blind via. Release film A with 0.06mm can be used to make overflow resin thickness less than 6um. The resin could be removed by the combination of desmear and micro-etch process.

The process mentioned below can be used to eliminate the overflow resin:
→(PTFE cores fabrication) → brown-oxidation of the cores → hot/cool press → micro-etching → desmear →micro-etch → (drilling) → (plasma active and PTH)→ ……
(Note: The processes in brackets are common FR4 fabrication process.)

Reference

1. Cai jiqing, "PTFE-based Composites for high-speed Digital Designs", Printed Circuit Information, Jan 2003.

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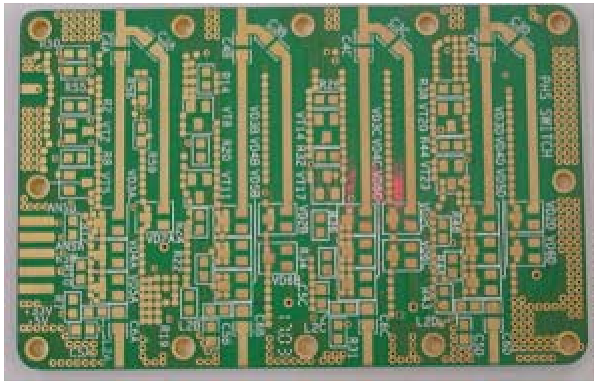
2004年3月23

Why we need hybrid PCB!

- Low cost
- High performance
- High reliability
- Easy to production



Common structure

- Rogers 4000's + FR-4 prepreg
- GML 2000's + FR-4 prepreg
- GML 2000's + Rogers 4403 bonding film
- PTFE + FR-4 prepreg

PTFE-FR4 is focused on

- PTFE-FR4 hybrid PCB technology is applied more and more widely. This technology requires blind via fabric in PTFE core.

Material list (part)

Supplier names	Traditional types
Taconic	RF-35,TLX-8,TLC32,TLY-5,
Nelco	N9000, N9000-13RF, FV6700
Arlon	AD250,AD270,AD300,AD350, Diclad527
Rogers	Rogers3001,Rogers3003

Test factors

- Shrink-swell compensation
- Impedance calculation when reference different material
- Desmear and PTH
- Bonding force between PTFE active surface and FR4
- Overflow resin cleaning after lamination

Shrink-swell compensation

- : The shrinkage rates of PTFE and FR4 are different. Hybrid boards are more variable than that of common FR4 PCB.
- Additionally, the shrinkage rate can be measured and easily compensated in process.

Desmear and PTH

- Drilling parameters are calculated based on PTFE specification.
- Desmear is base on plasma.

Bonding force between PTFE active surface and FR4

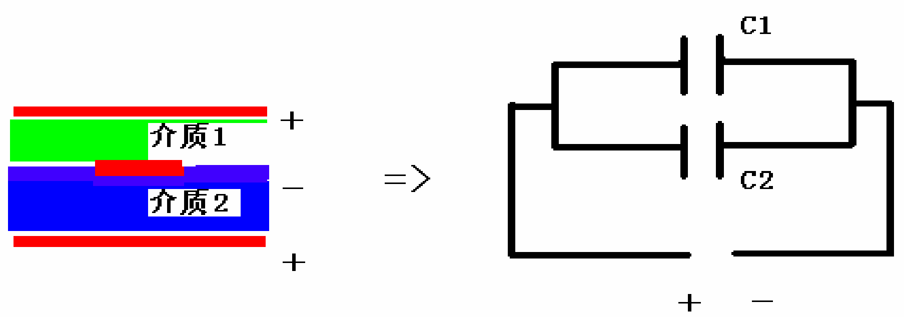
- The time internal between etching and laminating should be defined because active surface of PTFE core cannot exposed in the air for a long time. Otherwise active surface will be affected.

Impedance calculation when reference different material

- There have been set up a new formula for laminated boards with different dielectric capacity.

The permittivity calculation (1)

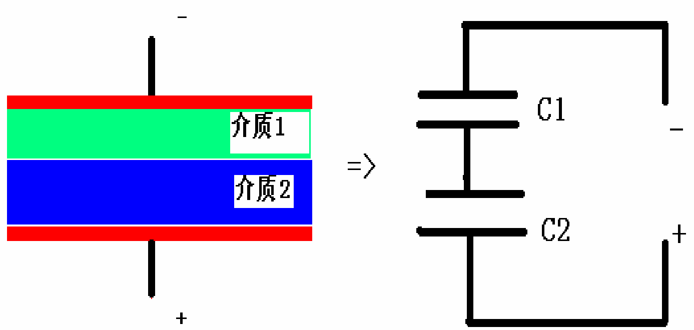
- Single ended structure:
  offset stripline



$$\varepsilon_{all} = \frac{\varepsilon_1 T_2 + \varepsilon_2 T_1}{T_1 + T_2}$$

The permittivity calculation (2)

- Single ended structure:
  surface microstrip



$$\varepsilon_{all} = \frac{(T_1 + T_2)\varepsilon_1\varepsilon_2}{\varepsilon_2 T_1 + \varepsilon_1 T_2}$$

Overflow resin cleaning after lamination

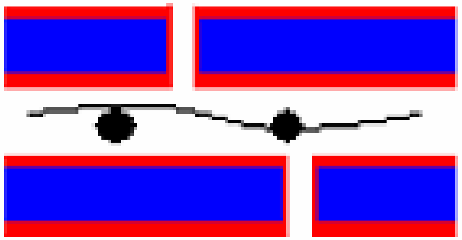
- For hybrid pcb with PTFE core and FR4 propreg, PTFE fabricating process is very special. For example, It's very difficult to use common mechanical brush to eliminate overflowed resin during surface treating. Except the special requirement for surface treating, overflow resin performance is the key to fabrication.

The factors of test

- Overflow resin thickness controling
- Overflow resin treating

Overflow resin thickness controling

- Release film A: 0.06mm.
- Release film B: 0.127mm



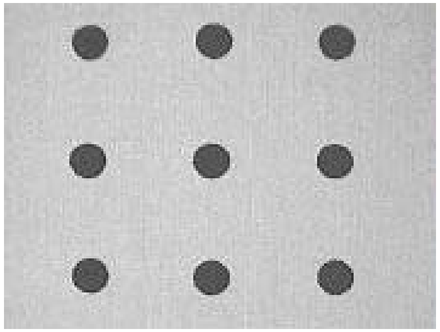
We choice film A

- For film B, resin stream out around the orifice. The width of resin annulus is about 0.3mm. And surface is wrinkle. For film B, resin flows evenly.
- For film B, the infilling capability change with hole diameter. The larger the orifice diameter is, the worse the infilling capability. The deepest concave is 148.3um.
- For film A, the infilling capability also change with hole diameter, Changing from 0.3mm to 1.5mm, the depth of concave offset range is only 1.3um. Additionally, the deepest concave is 31.28um.

Overflow resin treating

- Chemical desmear($KaMnO_4$)
- Micro-etch (APS)

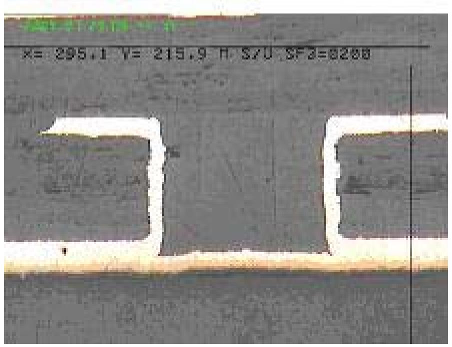
After desmear



micro-etch

For film A, the process flow

- Micro-etch→
- Desmear one time→
- Micro-etch



conclusion

- In the fabrication of PTFE-FR4 laminated PCB with blind via, the key point is how to control resin thickness and eliminate the resin that overflowed from the blind via. Release film A with 0.06mm can be used to make overflow resin thickness less than 6um. The resin could be removed by the combination of desmear and micro-etch process.

- The process mentioned below can be used to eliminate the overflow resin:
- ……→(PTFE cores fabrication) → brown-oxidation of the cores → hot/cool press → micro-etching → desmear →micro-etch → (drilling) → (plasma active and PTH)→ ……

Thanks