Hybrid Materials Alternatives for Optimum Assembly

by Alan Cochrane

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The use of hybrid technology (mixing of dissimilar materials in a multilayer package) has been done for quite some time. The typical driver for this mixing of materials is to allow for the required electrical parameters to be achieved. These materials are typically PTFE-based due to the superior electrical performance. However, these materials do not possess the required mechanical attributes (flexural strength) to allow for proper assembly.

PTFE Based

Flexural Strength (MD)	ASTM D 790/ IPC-650 2.4.4	psi	11,811	N/mm^2	81
Flexural Strength (CD)	ASTM D 790/ IPC-650 2.4.4	psi	7,512	N/mm^2	51

Epoxy Hydrocarbon

Flexural Strength	276 (40)	255 (37)		MPa (kpsi)		IPC-TM-650 2.4.4

Modified Epoxy

Flexural Strength			
Lengthwise	> 60,000 psi	A	> 60,000 psi
Crosswise	> 50,000 psi	A	> 50,000 psi

The data illustrates the dramatic difference in the strength of the materials. Therefore it is required to add an additional material to provide the proper strength to the final assembly.

Following are the electrical attributes for the same above noted materials.

PTFE Based

Property	Test Method	Unit	Value	Unit	Value
Dk @ 10 GHz	IPC-650 2.5.5.5.1 (Modified)		3.00		3.00
T_cK (-30 to 120 °C)	IPC-650 2.5.5.5.1 (Modified)	ppm	5.4	ppm	5.4
Df @ 10 GHz	IPC-650 2.5.5.5.1 (Modified)		0.0011		0.0011

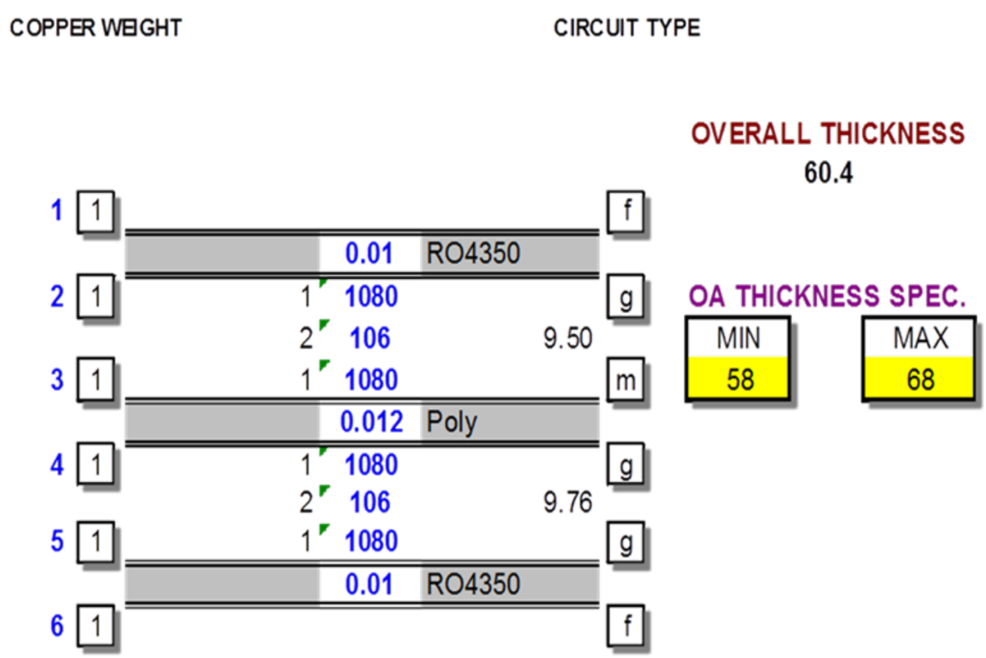
Epoxy Hydrocarbon

Dielectric Constant, ε_r Process	3.38 ± 0.05	(2) 3.48 ± 0.05	Z	--	10 GHz/23°C	IPC-TM-650 2.5.5.5 Clamped Stripline
(1) Dielectric Constant, ε_r Design	3.55	3.66	Z	--	8 to 40 GHz	Differential Phase Length Method
Dissipation Factor tan, δ	0.0027 0.0021	0.0037 0.0031	Z	--	10 GHz/23°C 2.5 GHz/23°C	IPC-TM-650 2.5.5.5

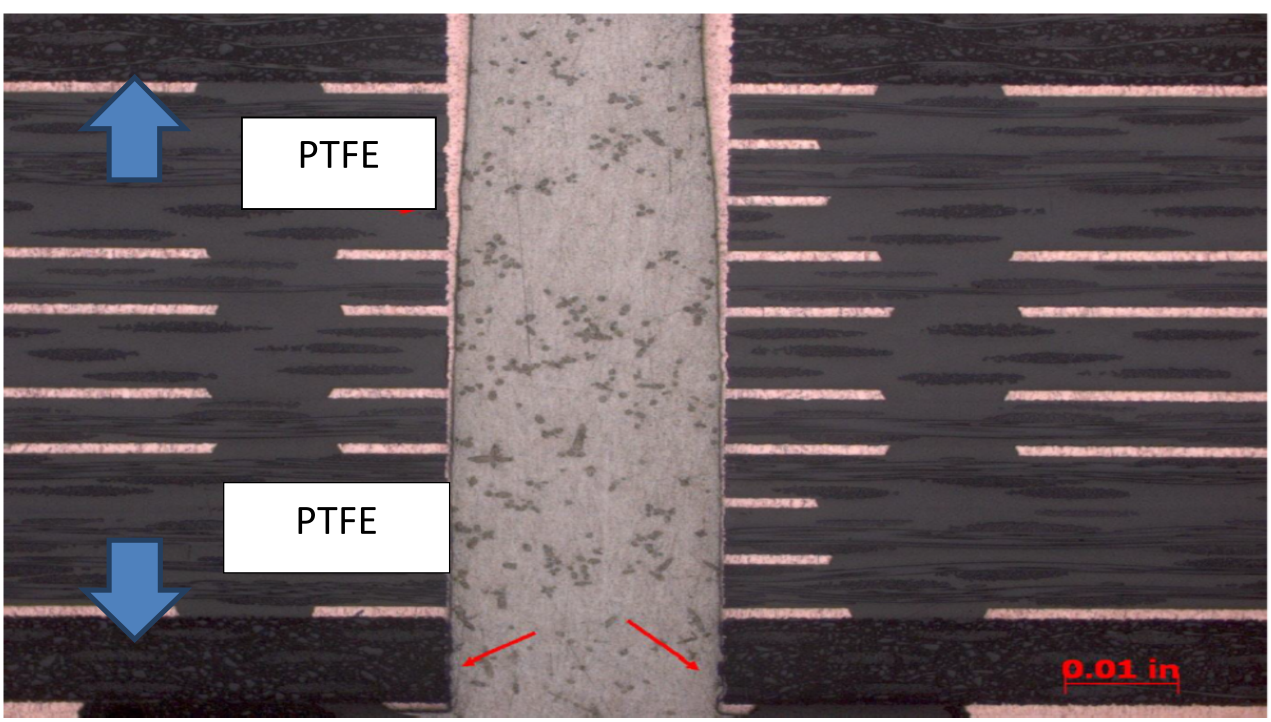
Modified Epoxy

Permittivity (RC50%) 10 GHz (SPC method)	3.4	C-24/23/50	N/A
Loss Tangent (RC50%) 10 GHz (SPC method)	0.0025	C-24/23/50	N/A

This data originates from the published data sheets of these specific materials. The electrical properties are very close or better, dependent upon which attribute being viewed. Signal integrity testing at major OEMs worldwide has shown the modified epoxy has an actual improvement over the competition by a range of 1–13%. This is specific to actual loss data measured in db/in via S21 parameter test set measured out to 40 Ghz.



12 layer version



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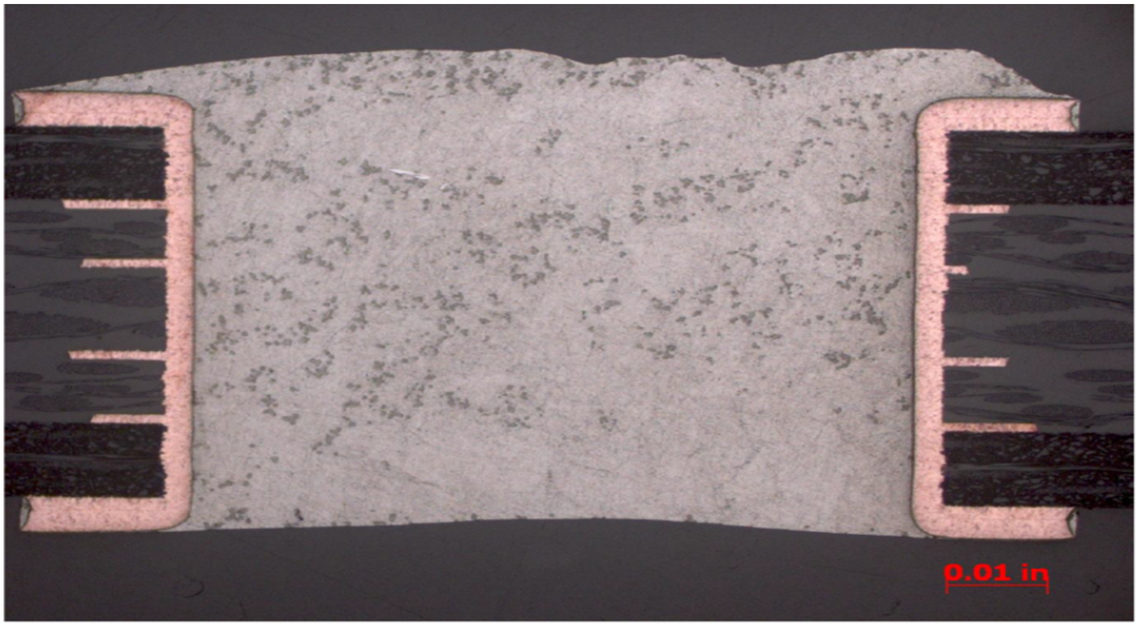
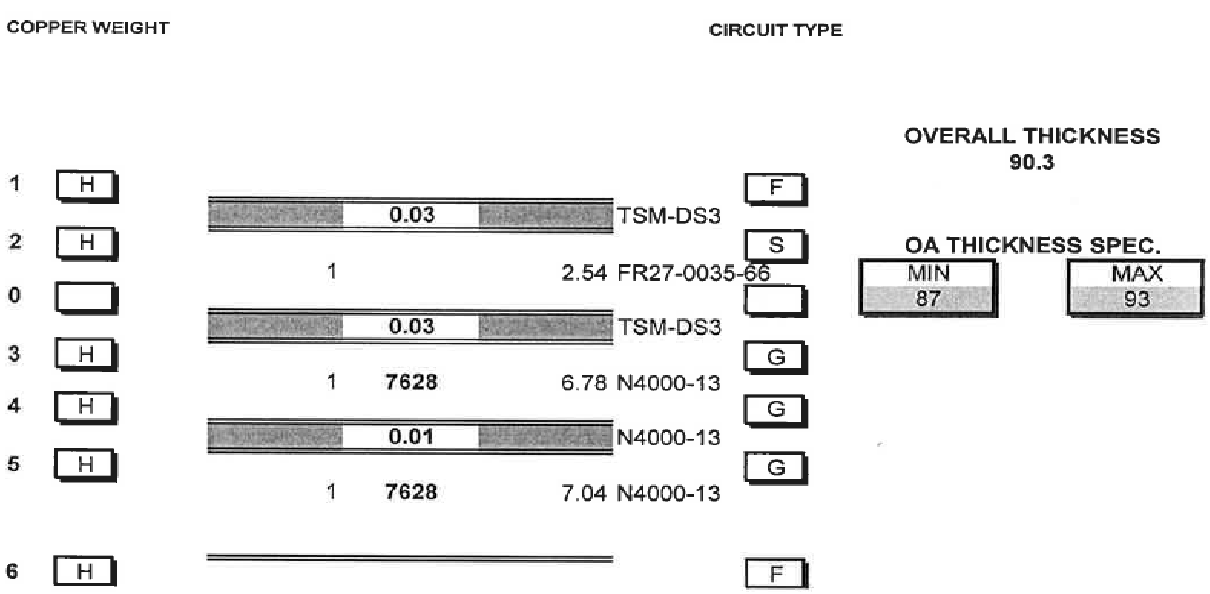
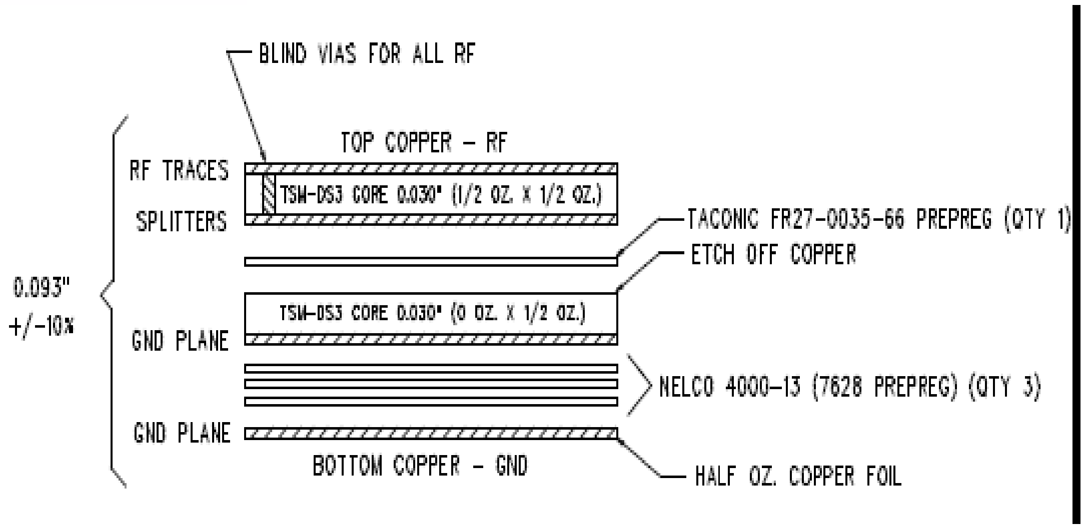
6 Layer Version



Often, in an effort to reduce cost, the design will have a single layer of PTFE or 2 layers for stripline configurations.





This configuration results in a great deal of warpage. Some of this warpage can be mitigated by panel size and construction. A proper DOE is required to determine the effectiveness of the changes. The following results are based on looking at cross-ply constructions (as the PTFE in this case is woven) of both the epoxy cores and epoxy pre-pregs.

		4 layer warpage Test					
		Warpage					
TSM	**Nelco**	**X**	**Y**		**AVE**		**SN**
12x21G	12x21G	0.143	0.22		0.1815		,005,006
12x21G	12Gx21	0.146	0.107		0.1265		,001,002
12x21G	12Gx21x12G	.250->.250	>.250				,007,008
12x21G	21Gx12x21G	0.088	0.153		0.1205		,003,004
SN	**Topside up**	**Bottom Side up**		**AVE**	**Rank**		
001	0.235	0.141		0.188	**8**		
002	0.075	0.095		0.085	**3**		
003	**0.043**	**0.046**		**0.0445**	**2**		
004	**0.022**	**0.041**		**0.0315**	**1**		
005	0.061	0.143		0.102	**4**		
006	0.098	0.117		0.1075	**5**		
007	0.12	0.25		0.185	**7**		
008	0.14	0.17		0.155	**6**		
				Min			
				0.0315			
				Max			
				0.188			

Clearly, the anticipated effect was not obtained and the common grain resulted in the least amount of warpage. The same testing was done of the 6-layer version and showed similar results. Note: In the above data, the cross-ply construction rank was 3&8 respectively, so it was pretty close. At the time of this writing, results of the assembly process were not available, as the product must still undergo simulated reflow and then re-tested to determine the final results. Serial number 3&4 were loaded with components as well. This design had limited components (SMA edge connectors and resistors) so the additional surface tension from the component assembly should be minimal.

The types of constructions noted above are costly and problematic, for the following reasons:

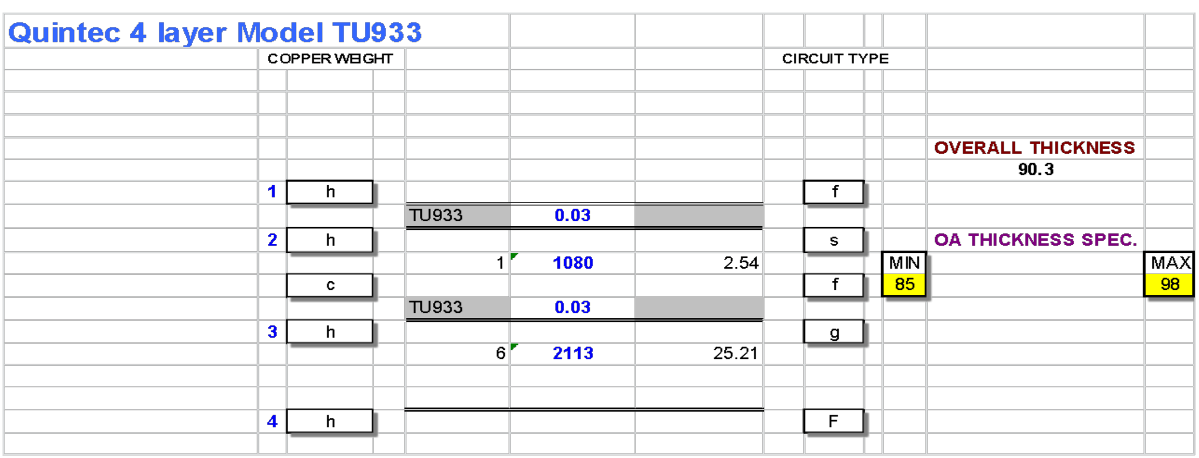
1. Core vs. foil construction
2. Different in plane CTE
3. Sequential lamination potential
4. Material cost
5. Material availability
6. Extensive lamination cycles
7. Special processing equipment
8. Thickness limitations

Moving to the alternative constructions eliminates all of the above noted problems.

A number of modified epoxy materials that have very similar electrical properties to the current high-speed version of PTFE and epoxy hydrocarbon include:

- TUC TU-933
- Isola Tachyon-100G
- Nelco Meteorwave 2000
- Hitachi Lightwave

Direct change (still core construction)



Alternative Standard Core Construction

4 LAYER MODEL TU933

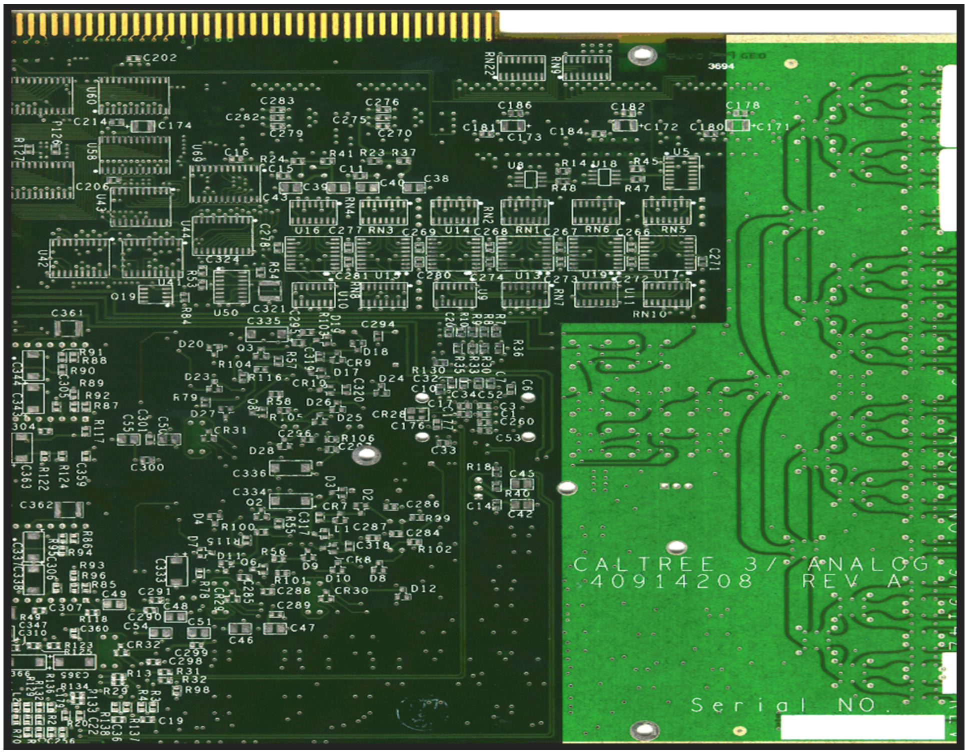
	COPPER WEIGHT				CIRCUIT TYPE			
1	h				F			
							OVERALL THICKNESS	
		6	2116	28.69			90.5	
2	h				S			
		TU 933	0.03					
3	h				G		OA THICKNESS SPEC.	
		6	2116	29.18		MIN		MAX
4	h				f	85		98

In both cases above, the result to the end customer was *reduced cost and improved delivery*. As the customer was cautious about the construction changes, the "direct change" was done first, followed shortly thereafter with the "alternative." The final "alternative" construction resulted in an increase in yield and even further cost reduction.

In some cases, hybrid designs have select "patches" of PTFE materials on the surface. For this product we see both high speed digital and RF on the same surface. These types of designs are also highly prone to warpage.

Products of these types are much more difficult to offer alternatives to, as the space requirements for the digital side do not allow for enough area for proper trace length to achieve to proper signal timing due to the propagation delay of the PTFE-based materials. However, the same modified epoxy material can be substituted to achieve similar results and reduce cost.

Same Plane Hybrid



With today's hybrid materials and an acute understanding of how to best utilize them, cost effective solutions for optimum assembly are possible for commercial and military RF needs.

About the Author:

Multilayer CTO Alan Cochrane has been involved in PCB design and fabrication since 1978. The majority of this time was spent in RF design and testing for military applications. With degrees in both electrical and mechanical engineering, Alan has presented tutorial information worldwide to major OEMs and fabricators. He was a main contributor to the design and fabrication of the Globalstar Satellite System, which resulted in numerous groundbreaking methods in PTFE multilayer fabrication.

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