Laminate Basics for Stackup Design

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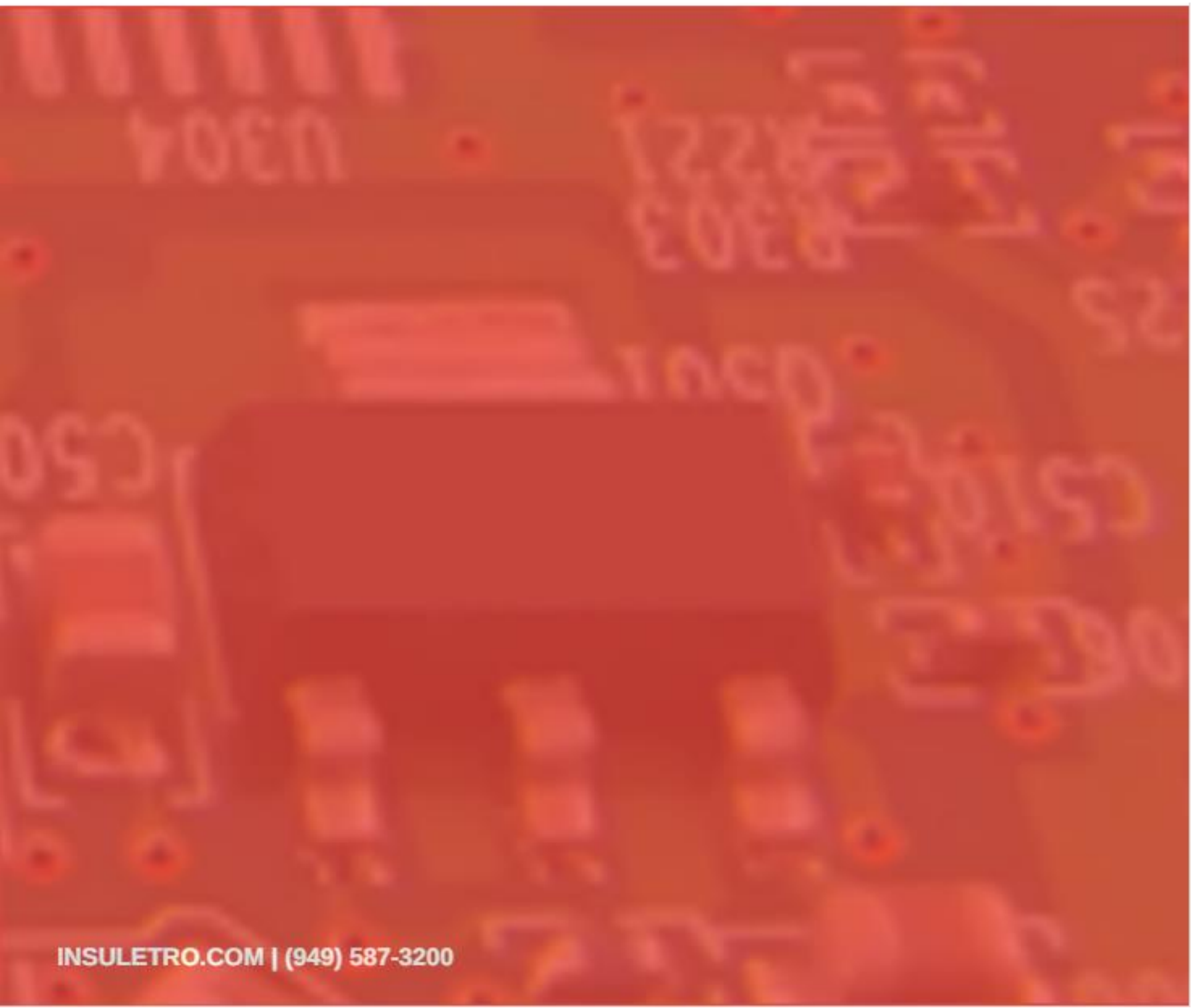
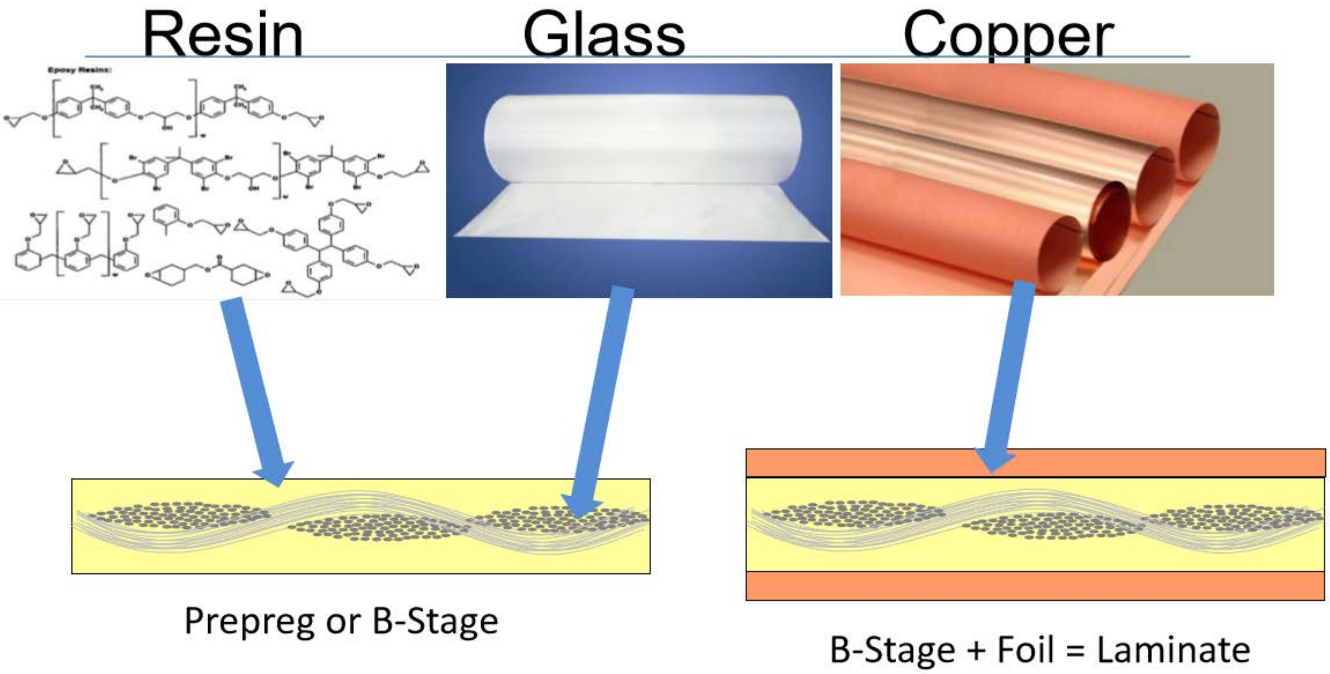


TABLE OF CONTENTS

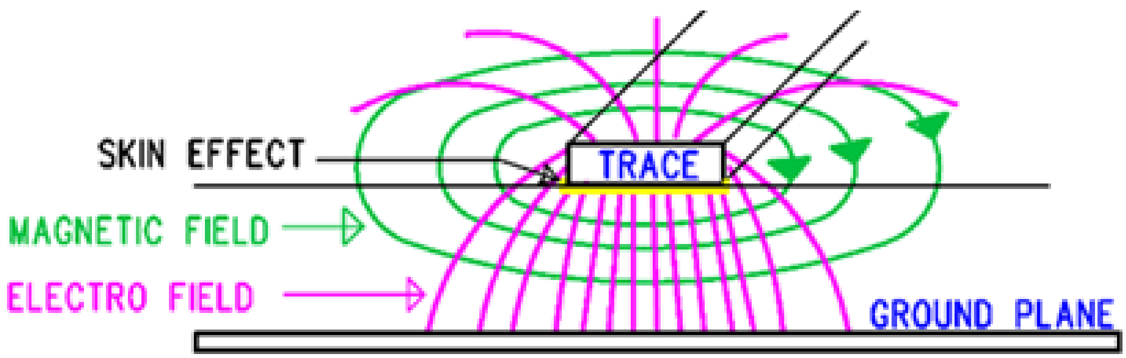


ABSTRACT

Laminates are comprised of three basic elements: Resin, Glass-weave and Copper. The resin is for bonding, the glass-weave is for rigidity, and the copper is for conductivity. Each element plays a vital role in establishing physical, electrical, and fabrication parameters.

BACKGROUND

Recently I was asked to write an article about stackup creation for an industry technical publication, I paused at the magnitude of this subject. It is similar to the framework used to pour concrete cement, meaning I sure hope you get it right because so many things can be affected by this and shape the success or failure of our circuits. In writing the newest training manual due out early this year, I observed that the longest chapter in the textbook was dedicated to this subject. Therefore, I believe it is truly one of the most important and reaching subjects in our industry.

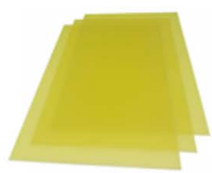


Electro-Magnetic (EM) Field Effect in Materials

THREE ELEMENTS COMPRISING RIGID LAMINATES

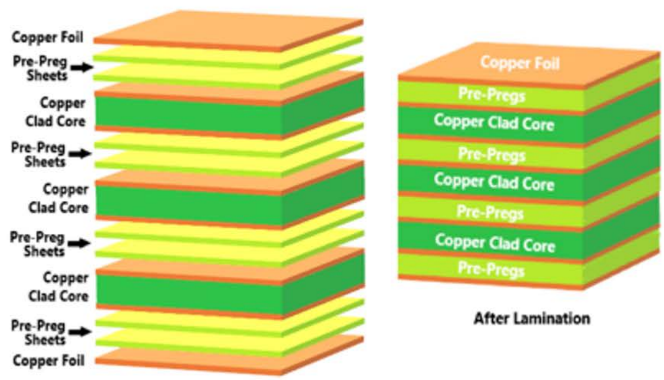
The laminates for rigid boards come in two basic forms (Copper Clad and Prepreg) and are built in an alternating fashion from the center of the stackup outward. The prepreg acts as a joining agent between two cores or a core and external copper foil layer.

Epoxy Materials Construction



Prepreg "B-Stage"

Copper Clad Core "C-Stage"



Bare Board Balanced 8-Layer Alternating Construction

RIGID LAMINATE TYPES AND BALENCED CONSTRUCTION METHOD

Laminates have physical and electrical parameters which affect performance and manufacturing process. These laminates and copper foils are supplied in many thicknesses and are used in a multitude of combinations, all of which your fabricator is the best source to help you find a working solution. Below are samples of the Isola and DuPont product ladders showing varied laminate selections indicating these values.

ISOLA RIGID PRODUCT LADER

ISOLA Product	ISOLA products compatible for Hybrid Builds	Gbps	IPC Slash Sheets,UL, Comments and Recommended Bit Rate/Flame Rating & Frequency range	Max Operating Temp	Tg By TMA	Td	Dk	Df	VLP 2 Foil
370HR	185HR, 408HR, I-Speed, I-Tera, Tachyon 100G, Astra	2 to 3 max	IPC-4101 /101 /98 /99 /126 UL E41625 Legacy High rel and lead free comp. FR4V-0 94	130 °C	180	340	4.04	0.0210	N/A
FR408HR	185HR, 370HR, I-Speed, I-Tera , Tachyon 100G, Astra	up to 12	IPC-4101 /98 /99 /101 /126 UL -E41625 Multifunctional low loss resin V-0 94	130 °C	190	360	3.68	0.0092	Available
I-Speed®	185HR, 370HR, 408HR, I-Tera, Tach 100G, Astra	Up to 20	IPC-4101 /98 /99 /101 /126 UL-E41625 Best Signal performace at this cost. V-0 94	130 °C	180	360	3.64	0.0060	Standard
I-Tera® MT40	185HR, 370HR, 408HR, I-Speed, Tach 100G, Astra	Up to 60	IPC-4103 /17 UL-E41625 Very good signal and thermal performance V-0 94	130 °C	200	360	3.45	0.0031	Available
TerraGreen®	IS550H	Up to 77	IPC-4103 /17 UL-E41625 Halogen Free version of I-Tera MT40 V-0 94	130 °C	200	390	3.44	0.0039	Available
P95/P25	P96/ P26 *370HR when cured @ 375˚F	up to 5	IPC-4101 /40/41 UL-E41625 HB-94 No Flow version of Prepreg available	140 °C	260	416	3.76	0.0170	N/A
Tachyon® 100G	185HR, 370HR, 408HR, I-Speed, I-Tera , Astra	Up to 125	IPC-4103 /17 UL-E41625 Ultra low loss and low Dk for HSD app. V-0 94	130 °C	200	360	3.02	0.0021	Standard
Astra® MT77	185HR, 370HR, 408HR, I-Speed, I-Tera, Tach. 100G	Up to 125	IPC-4103 /17 UL-E41625 Ultra Low loss, Low Dk alt. RF V-0 94	130 °C	200	360	3	0.0017	Standard

DUPONT™ FLEX POLYIMIDE PRODUCT LADDER

Property	Unit	Method	Kapton® HN	Pyralux® AP	Pyralux® AG	Pyralux® HT Bondfilm	Pyralux® TK
Thicknesses	mil	–	1 - 5	1 - 6	1 - 2	1-4	2 – 4
Dk @ 10 GHz	–	Method 2.5.5.5	3.4	3.2	3.2	3.0	2.5
Df @ 10 GHz	–	Method 2.5.5.5	0.010	0.002 - 0.003	0.007	0.003	0.002
% Moisture uptake	%	Method 2.6.2	2.8	0.8	0.8	0.8	0.6
CTE (x-y axis)	ppm/°C	50 to 250 °C	20	25	17-20	25	27
CTE (z axis)	ppm/°C	50 to 250 °C	115	90	90	90	102
Peel strength	N/mm	IPC-TM650	N/A	2.0 (ED) 1.6 (RA)	2.0 (ED) 1.6 (RA)	N/A	1.2 (RA)
Tg	°C	DMA	360 - 410	220	230	220	270
Tm	°C	DSC	–	–	–	–	300
Flammability	–	UL94	V-0	V-0	V-0	V-0	V-0

Physical (thermal) parameters are:

- (Tg) Glass Transition – is the transition temperature at the lower end of the thermal excursion, whereby, the resin changes from a semi-solid state to a rubbery state. This is very important for high layer count boards.
- (Td) Decomposition Temperature - is at the higher end of the thermal excursion, whereby, the material may start to decompose or breakdown from excess heat. This is very important for boards that may experience multiple lamination cycles, such as HDI boards.
- (CTE) Coefficient of Thermal Expansion occurs in both the X/Y Axis and the Z Axis. The glass weave moves in the X/Y-Axis. This is of concern for warpage threatening solder joints. Boards are thin in the Z-Axis as compared to the X/Y-Axis; therefore, Z-Axis can be of greater concern as it threatens the reliability of plated holes.

Electrical parameters are:

- (E r or Dk) Dielectric Constant - also called permittivity or relative permittivity, is the ratio of capacitance of electrodes with a specific material. This is critical for impedance calculations and is of high value to High-Speed Digital circuits. It should be noted that approximate Dk of resin is 3.0 and glass weave is about 5.0 with a resultant equaling a Dk4.0.
- (Df) Dielectric Losses - is the absorption of electromagnetic energy by the board material in a varying electric field. This is critical for minimizing db loss calculations and is of high value to RF circuits.

Copper:

Comes in several forms such foil layers, electro-deposited or electro-plated. Copper foil is typically utilized on the outer two layers and it has a smooth side and a rough side. The rough side provides adhesion to the resin in the prepreg and the smooth side is better suited as an energy transfer surface reducing energy loss.

Conclusion

There are many laminate choices in our industry. Yes, I think ours are the best and I'm always eager to make that case. But you the designer need to pick the best material for your needs, always working early with your supply chain. What I want you to remember is to get the best use from the best material by understanding all three perspectives (DFS, DFP & DFM) and not just pursuing one or two perspectives.

With our Design Education Program, we are eager to support signal-integrity reviews of design circuits prior to fabrication. Also, we are ready and eager to create one or several training sessions for the OEM or your fabrication team. These will be tailored to meet the exact needs of the audience, brought by a technically appropriate presenter, with specific content to further your team's success and provide that edge to meet the needs of advancing technology trends.