Altium

ALTIUMLIVE 2018:
NAVIGATING THE COMPLEXITIES OF PCB MATERIAL SELECTION

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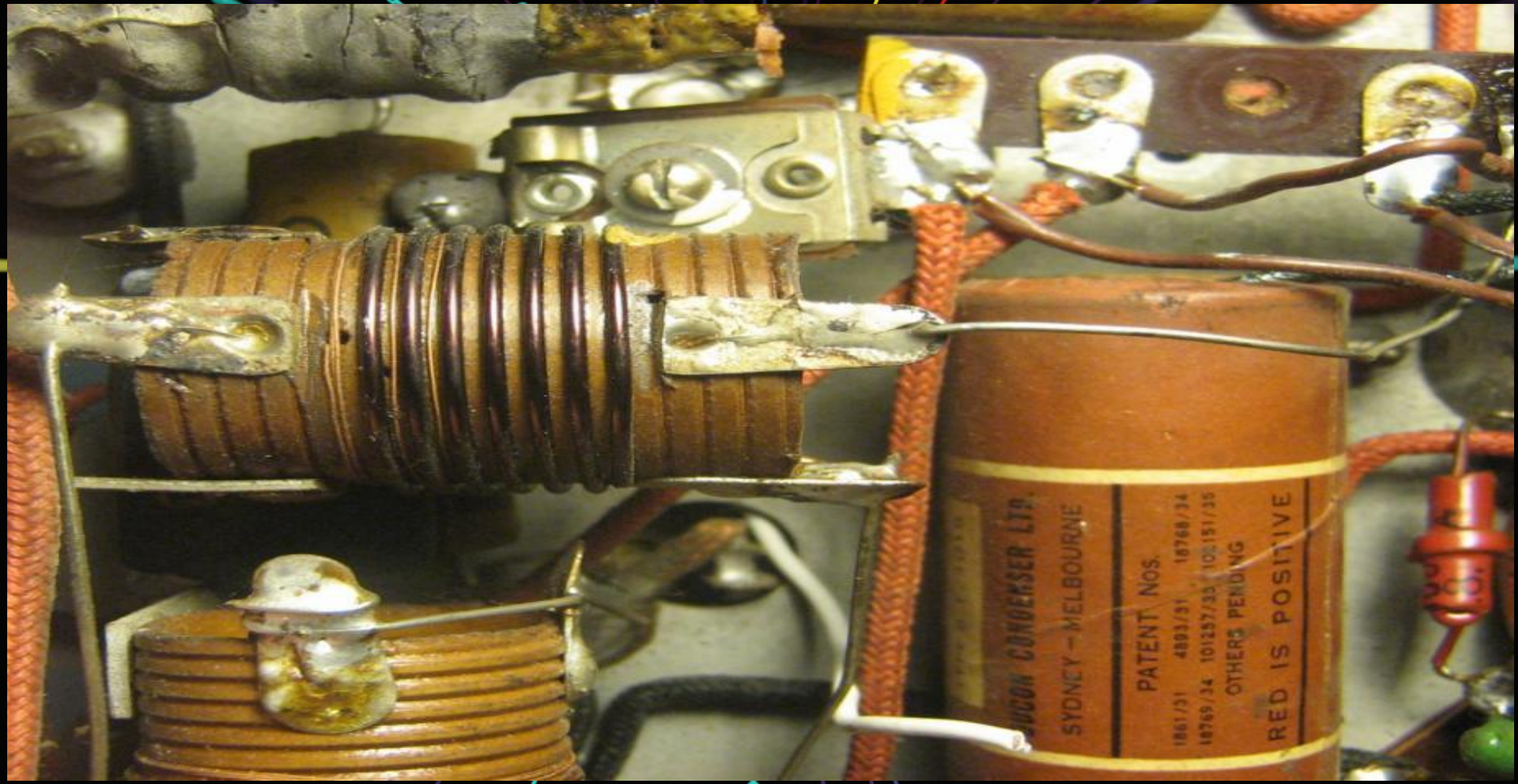
Outline

1. PCB Material Overview
2. What is the Dielectric Constant of a material?
3. Copper foil for making circuits
4. PCB building blocks: Prepregs
5. Best signal performance

Who needs a PCB?

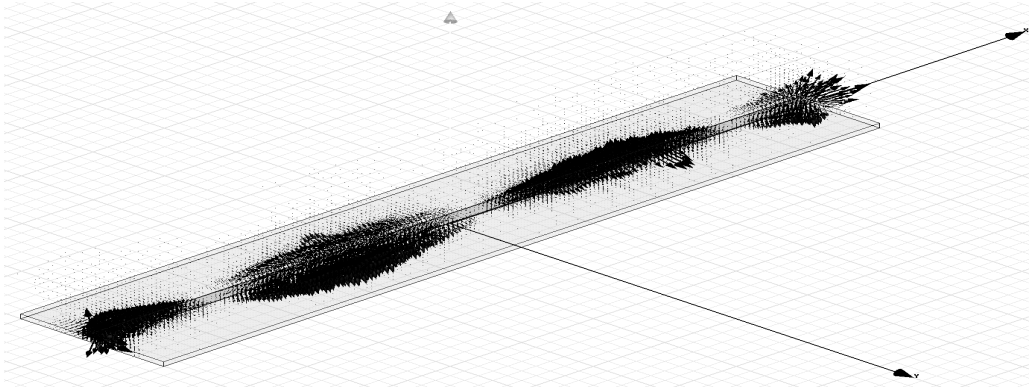


PCB (printed circuit board)

- Supports components and devices
  - *Holds everything together!!!*
- Electrically interconnects devices
- Transmission lines (data or RF)

MORE AND MORE its becoming electrically important!

Connecting point A and B are not enough, faster data requires better transmission lines for signals between components.

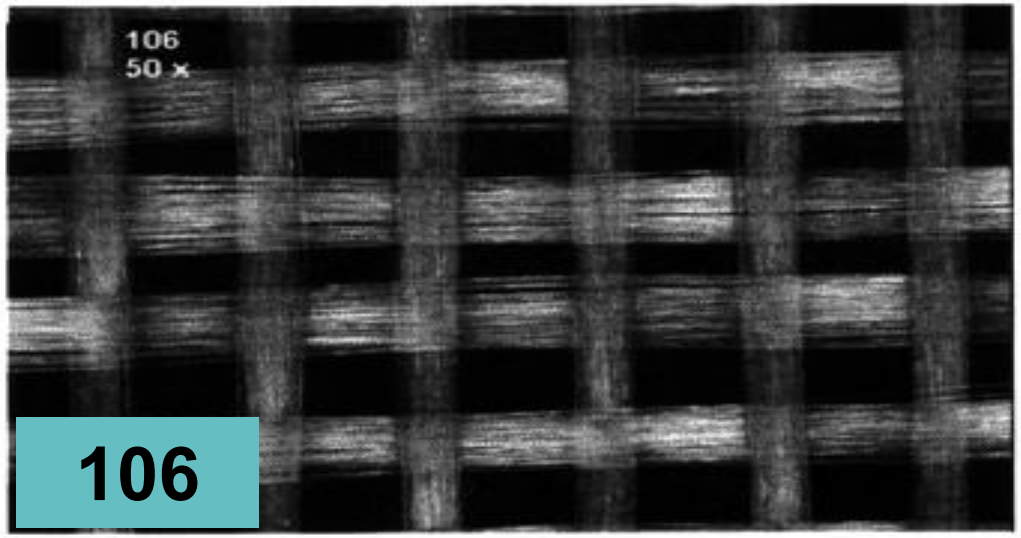


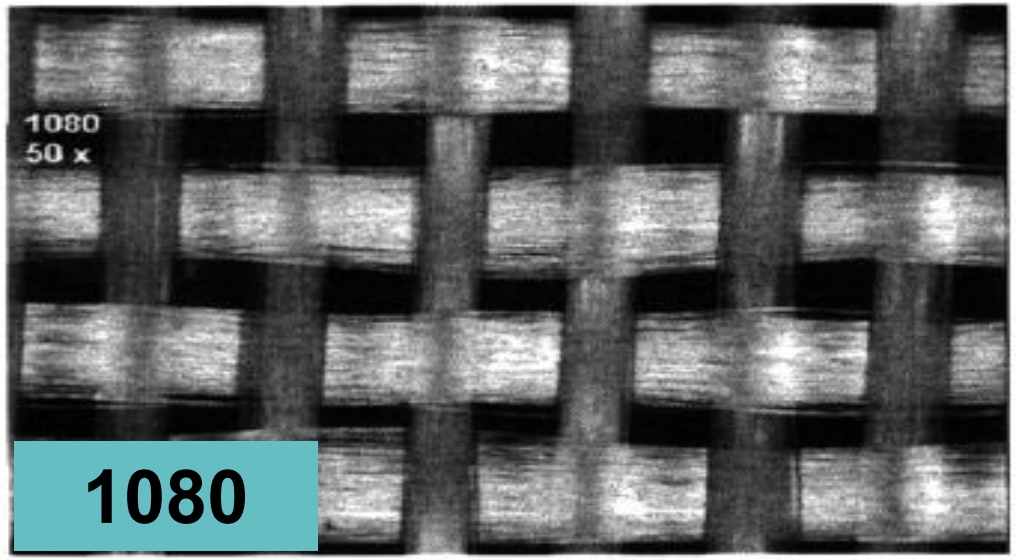
Two basic components for PCB’s

Conductors

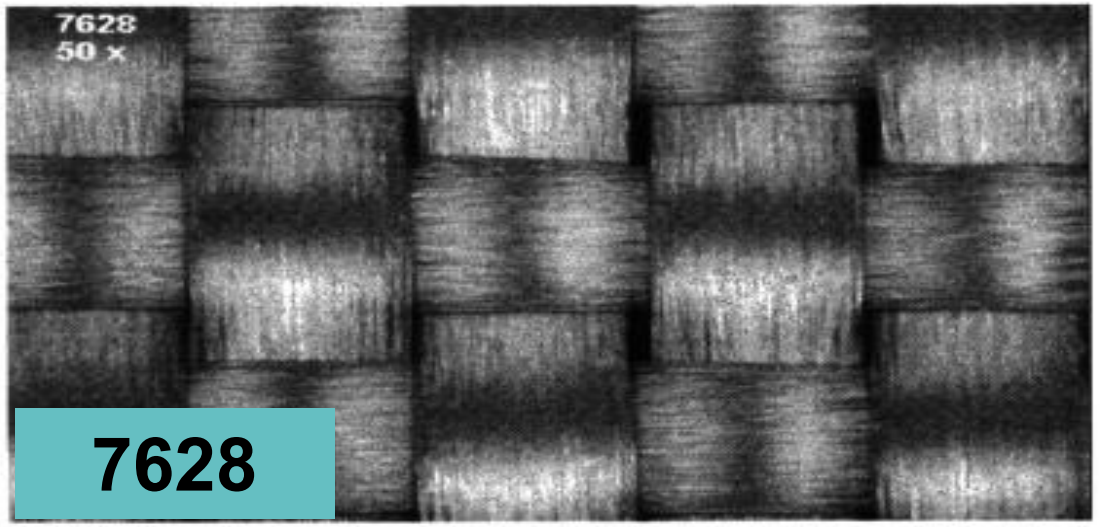
Dielectrics

Why Glass Fabric?

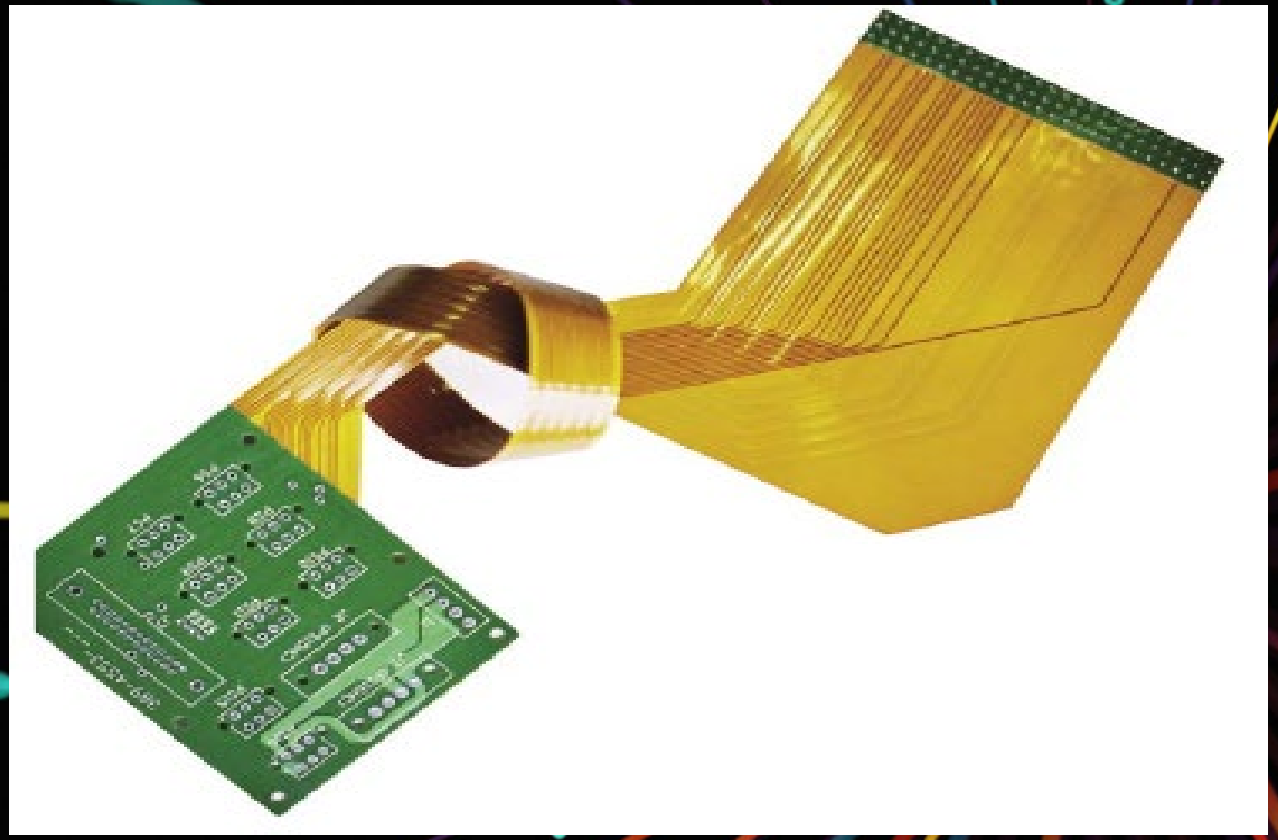


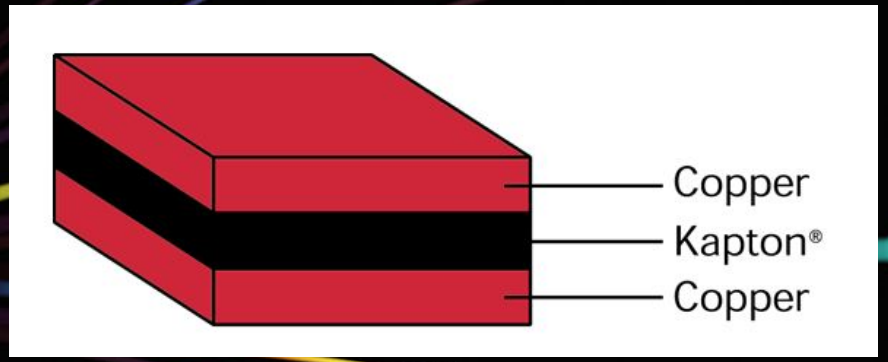


- In Fabrication
  - Supports B-Stage (prepreg)
  - Controls spacing
  - Cost



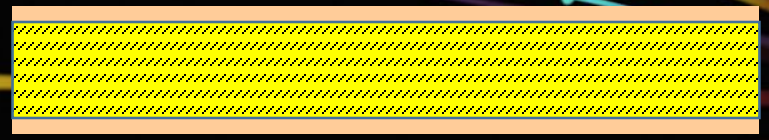
- In Use
  - Strength
  - Cost



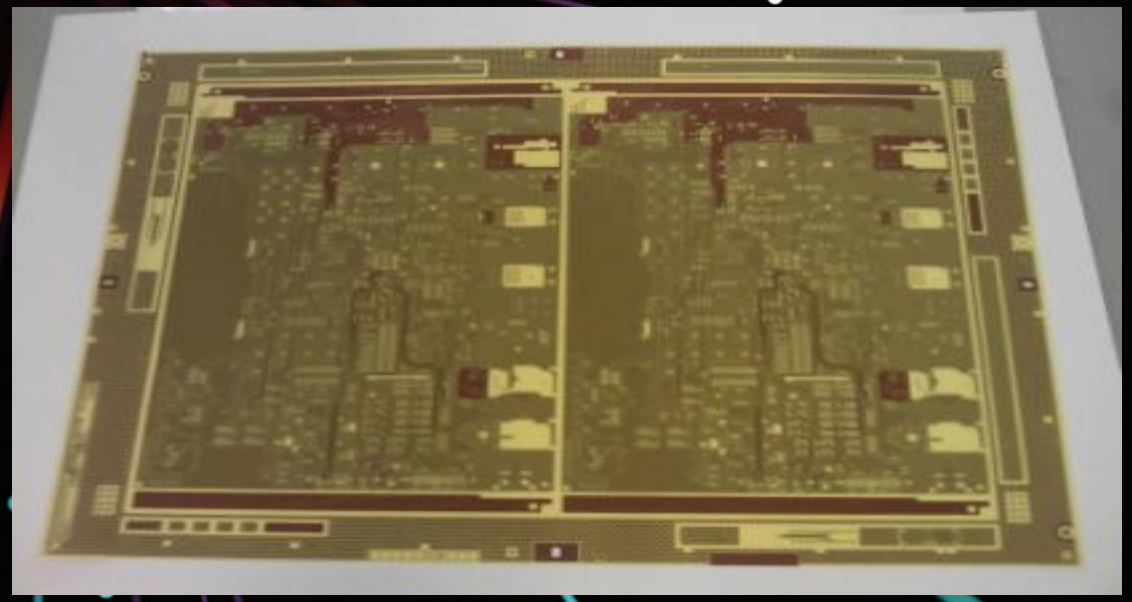


Flexible Circuits

Subtractively Processed PCB Layer

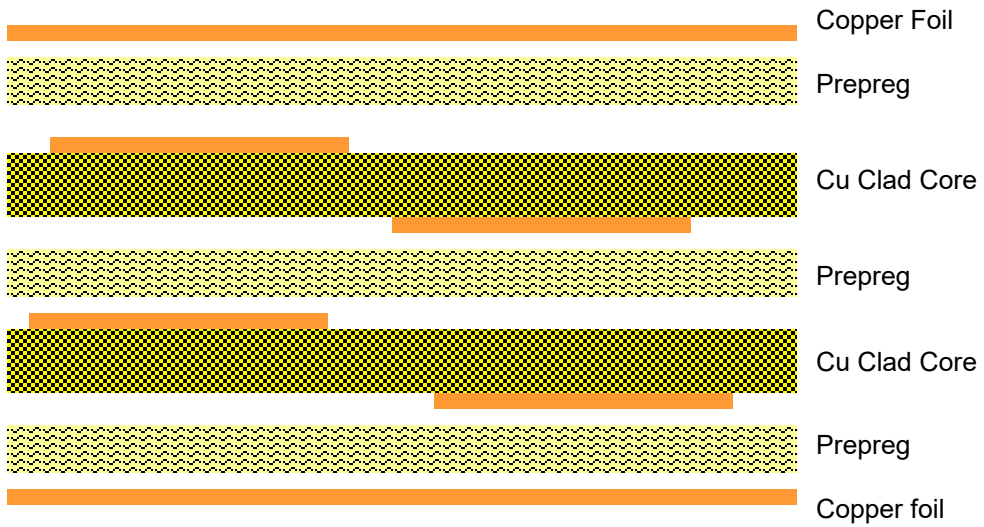


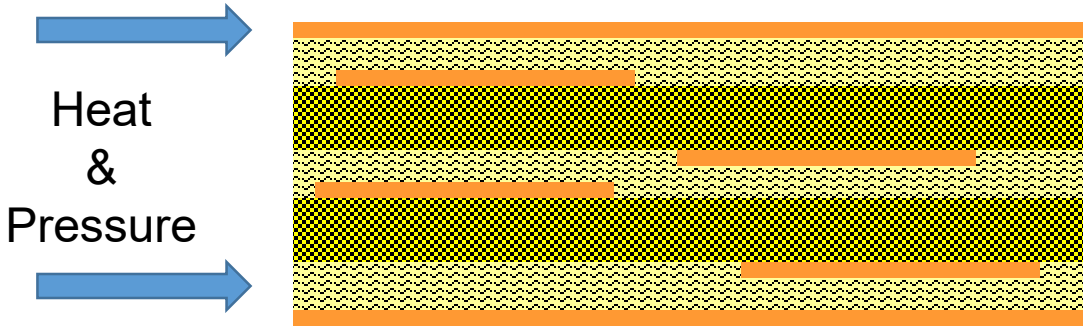
Side
View



PCB Materials: The Basics

- Start with rigid and thin core copper clad.
- Circuits are formed in the copper.
- The PrePreg is the “glue” to stack these layers (AKA: B-Stage).
- Copper foil or CAC is used on the outer most layers.
- Everything is aligned and then laminated with heat and pressure.

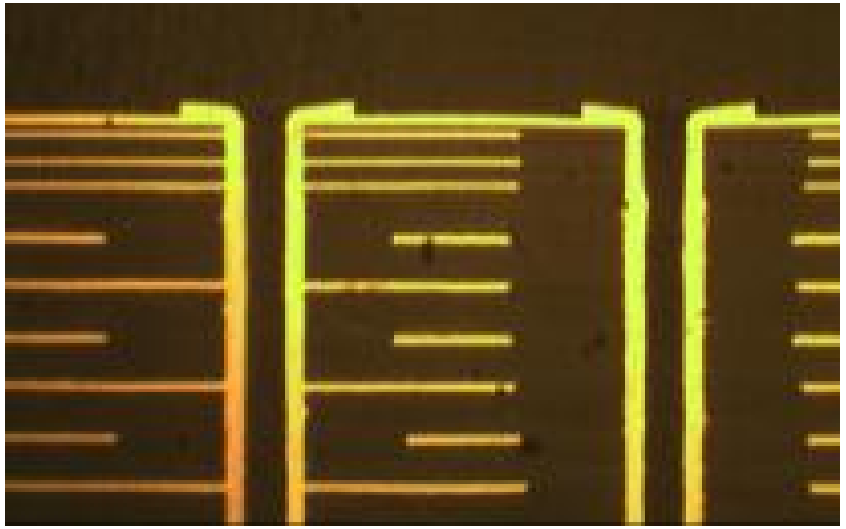


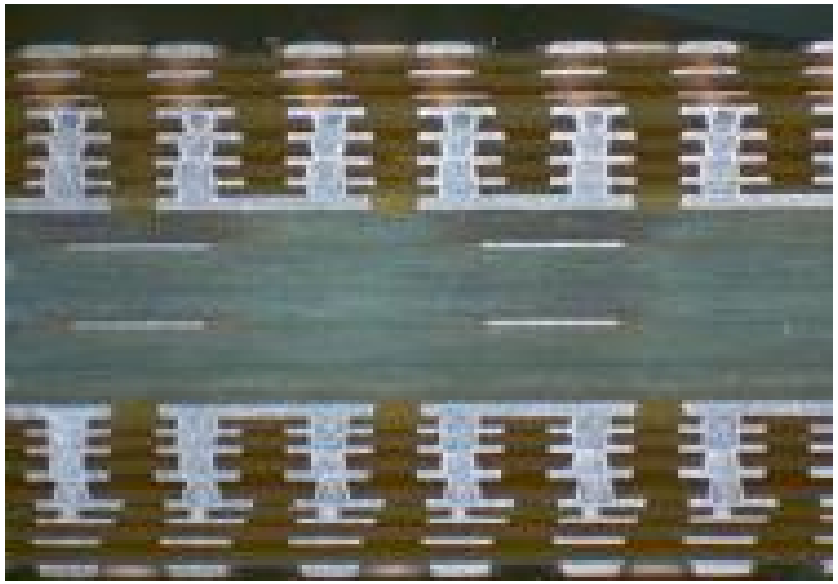


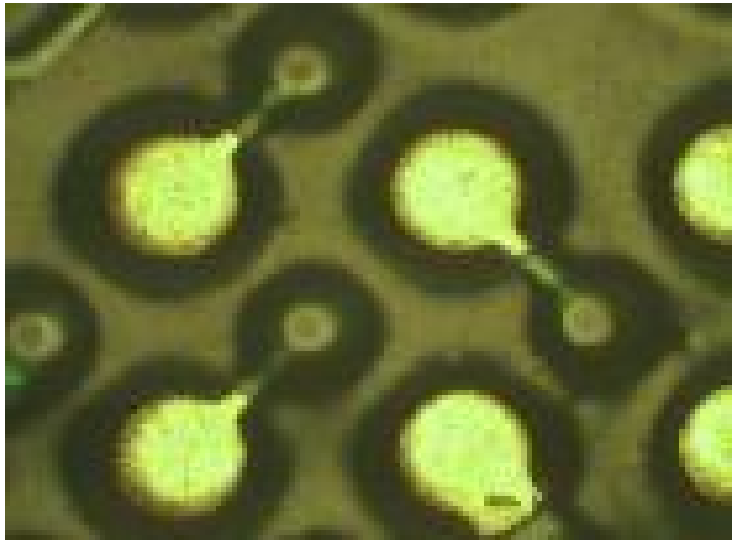
Some PCB Construction Terms

- Foil Lam
  - Copper foil bonded with prepreg to make the outermost circuit layers, usually where components are mounted.
- Cap Lam
  - Copper clad core is circuit image one side, then laminated to the outermost part of the PCB. The blank copper side will become the circuits and pads for components.
- Alternative Oxide
  - Bond treatment used on copper foil after imaging to increase resin adhesion.
- Buried Via
  - Copper plated via that links internal layers in the z-axis.
- Blind Via
  - Maybe surface or buried. Typically laser drilled, it is plated with one end open only.
- Sub Lam (Subs)
  - Multilayer components of a complex PCB built in stages with multiple lamination cycles.
- Via in Pad
  - Plated z-axis interconnect that is filled with additional copper or resin in a surface mount pad.
- Hybrid Construction
  - Use two or more types of resin systems in the same PCB.

Plating: Brining it Together







Plating or metal paste makes the interconnects between layers.

Material Properties

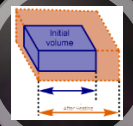
GLASS TRANSITION TEMPERATURE

Tg

DECOMPOSITION TEMPERATURE

Td

CTE



DIELECTRIC CONSTANT

Dk

DISSIPATION FACTOR

Df

Resin System Groups

Epoxy

- FR-4 (most common)
- High adhesion
- Economical
- Good mechanicals
- Higher loss at higher frequencies
  - Some blends are higher performing.
- Filled and unfilled resin systems
- IPC-4101
  - 20/21/22/23/24/26/ 27/97/ 98 /99 /101 /126

Polyimide

- One of the highest in thermal performance
- High cost
- Low neat resin CTE
- Long history in aerospace.
- A little better than FR-4 for signal performance.
- Hygroscopic
- IPC-4101
  - /40 /41/ 43 /44

PPO/PPE Blends

- Lower loss than FR-4 epoxies.
- Higher cost
- With low Dk glass, can approach PFTE performance
- Most out perform epoxy thermally
- Lower adhesion than epoxy
- IPC-4101
  - /25/90/91/96 /102/ 103
- IPC-4103
  - /17

PTFE Systems

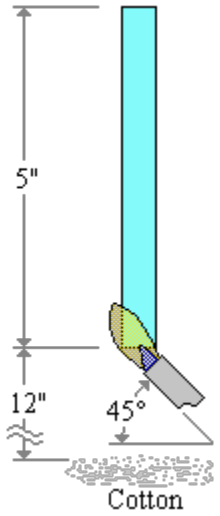
- Can be very low loss and low Dk
- Very high cost
- Needs reinforcement
- Low moisture absorbing
- Usually high temp and/or high pressure lamination.

Product	Tg by TMA	Td	Dk	Df	VLP Foil	PIM Sensitive applications	IPC Slash Sheets, Comments and Recommended Bit Rate/ Frequency range	Number of lamination cycles	Compatible with for Hybrid Builds
185HR	180	340	4.01	0.02	N/A	N	IPC-4101 /98 /99 /101 /126 Low cost Lead Free solder compatible FR4 PCB 2 to 3 GHz max	3 to 4	370HR, 408HR, I-Speed, I-Tera MT40, Tachyon 100G, Astra MT77
370HR	180	340	4.04	0.021	N/A	N	IPC-4101 /101 /98 /99 /126 Legacy High rel and lead free compatible FR4 2 to 3 GHz max	3 to 4	185HR, 408HR, I-Speed, I-Tera MT40, Tachyon 100G, Astra MT77
FR408HR	190	360	3.68	0.0092	Available	N	IPC-4101 /98 /99 /101 /126 Multifunctional low loss resin up to 12 GHz	3 to 4	185HR, 370HR, I-Speed, I-Tera MT40, Tachyon 100G, Astra MT77
I-Speed®	180	360	3.64	0.006	Standard	N	IPC-4101 /98 /99 /101 /126 Best Signal performace at this cost. Up to 20 GHz	4 to 5	185HR, 370HR, 408HR, I-Tera MT40, Tachyon 100G, Astra MT77
I-Tera® MT40	200	360	3.45	0.0031	Available	N	IPC-4103 /17 Very good signal and thermal performance. Up to 60 GHz	10	185HR, 370HR, 408HR, I-Speed, Tachyon 100G, Astra MT77
I-Tera® MT40 (RF/MW)	200	360	3.38 / 3.45 / 3.60 / 3.75	0.0028 - 0.0035	Available	Yes, with VLP-2 foil	IPC-4103 /17 Same as I-Tera MT40, but Dk tuned for RF applications Up to 77 GHz	10	185HR, 370HR, 408HR, I-Speed, I-Tera MT40, Tachyon 100G, Astra MT77
TerraGreen®	200	390	3.44	0.0039	Available	N	IPC-4103 /17 Halogen Free version of I-Tera MT40 Up to 60 GHz	6	IS-300MD
TerraGreen® (RF/MW)	200	390	3.45	0.0032	Available	Yes, with VLP-2 foil	IPC-4103 /17 Halgen Free for RF Up to 77 GHz	6	IS-300MD
IS300MD	190	390	3.06	0.0033	Available	N	IPC-4103 /17 Low loss halogen free for thin build-up an mobile devices. Up to 60 GHz	6	TeraGreen
IS680	200	360	2.80-3.45	0.0025-0.0035	Available	N	IPC-4103 /17 Low cost PTFE alternaitve for double sided RF applications. Up to 77 GHZ	N/A	N/A double sided only
IS680 AG	200	360	3.00 / 3.38 / 3.45 / 3.48	0.0020 - 0.0029	Standard	Yes	IPC-4103 /17 Low cost double sided material for PIM sensitive RF applications. Up to 77 GHz	N/A	N/A double sided only
Tachyon® 100G	200	360	3.02	0.0021	Standard	N	IPC-4103 /17 Ultra low loss and low Dk for HSD applications. Up to 100 GHz	10	185HR, 370HR, 408HR, I-Speed, I-Tera MT40, Astra MT77
Astra® MT77	200	360	3	0.0017	Standard	Yes	IPC-4103 /17 Ultra Low loss and Low Dk alternative for RF multilayer applications. Up to 100 GHz	10	185HR, 370HR, 408HR, I-Speed, I-Tera MT40, Tachyon 100G

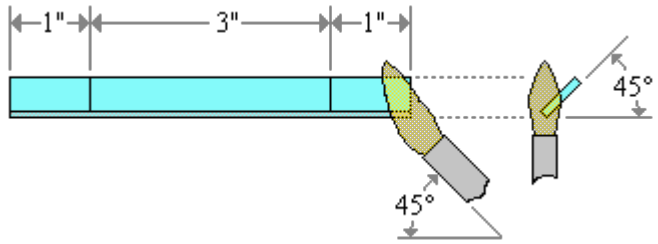
* Frequency range and number of lamination cycles are general guidelines and are influenced by the actual design * (7-30-2018)

UL Flame Ratings

UL flame ratings group materials into categories based on their flammability. UL 94 covers two types of testing: vertical burn and horizontal burn. In addition to V-0, V1 and V2 there is VTM (very thin materials) and 5V, 5V-A and B



Vertical Ratings	Requirements
V-0	• Specimens must not burn with flaming combustion for more than 10 seconds after either test flame application. • Total flaming combustion time must not exceed 50 seconds for each set of 5 specimens. • Specimens must not burn with flaming or glowing combustion up to the specimen holding clamp. • Specimens must not drip flaming particles that ignite the cotton. • No specimen can have glowing combustion remain for longer than 30 seconds after removal of the test flame.
V-1	• Specimens must not burn with flaming combustion for more than 30 seconds after either test flame application. • Total flaming combustion time must not exceed 250 seconds for each set of 5 specimens. • Specimens must not burn with flaming or glowing combustion up to the specimen holding clamp. • Specimens must not drip flaming particles that ignite the cotton. • No specimen can have glowing combustion remain for longer than 60 seconds after removal of the test flame.
V-2	• Specimens must not burn with flaming combustion for more than 30 seconds after either test flame application. • Total flaming combustion time must not exceed 250 seconds for each set of 5 specimens. • Specimens must not burn with flaming or glowing combustion up to the specimen holding clamp. • Specimens can drip flaming particles that ignite the cotton. • No specimen can have glowing combustion remain for longer than 60 seconds after removal of the test flame.



Horizontal Rating	Requirements
HB	• Specimens must not have a burning rate greater than 1.5 inches/minute for thicknesses between 0.120 and 0.500 inches and 3 inches/minute for thicknesses less than 0.120 inches. • Specimens must stop burning before the flame reaches the 4 inch mark.

PCB Flame retardants

- It’s important for a PCB to resist burning.
  - Almost all designs have circuits that carry enough current to start combustion under the right conditions.

- Flame retardants
  - Halogen: Bromine is the most common.
  - Non-Halogen:
    - Phosphorus compounds
    - Some metal hydroxides (aluminum, magnesium)

- Polyimide
  - Because of it’s high decomposition temperature, most pure polyimides (no flame retardants, epoxy) have an HB rating.

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2. What is the Dielectric Constant of a material?
3. PCB building blocks: Prepregs
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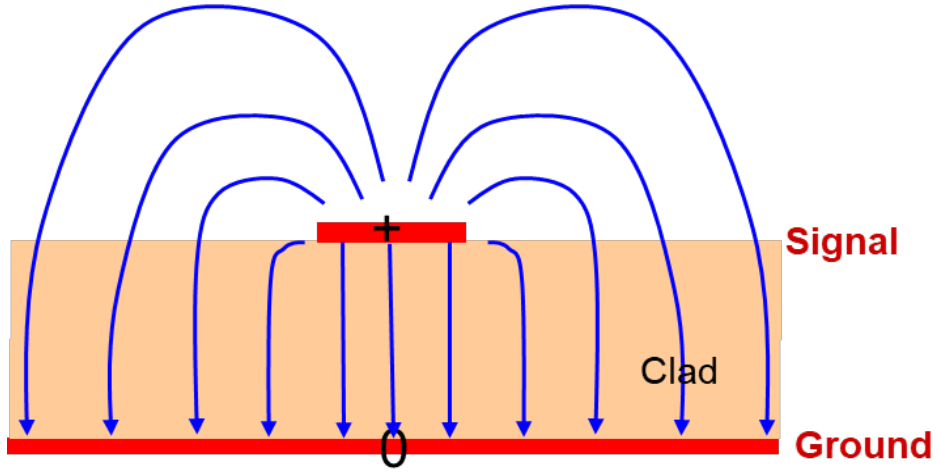
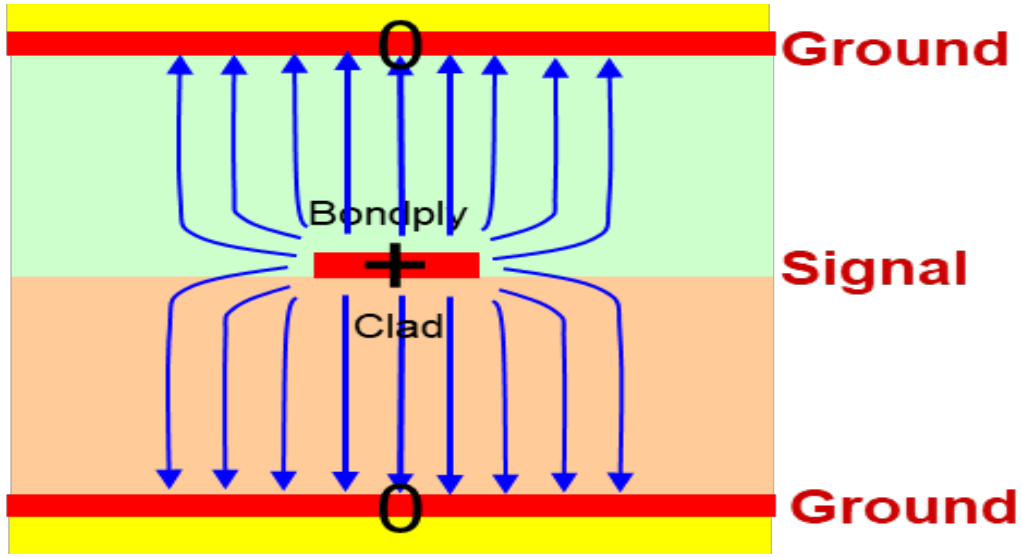
Permittivity, also known as Dielectric Constant

"a quantity measuring the ability of a substance to store electrical energy in an electric field."

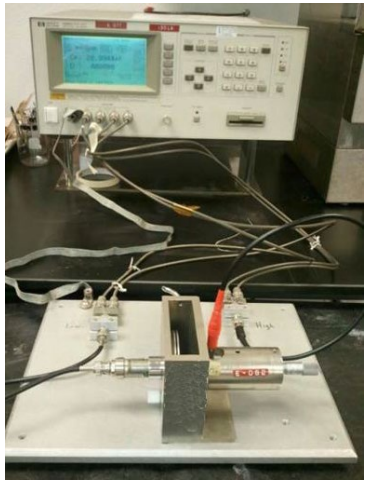


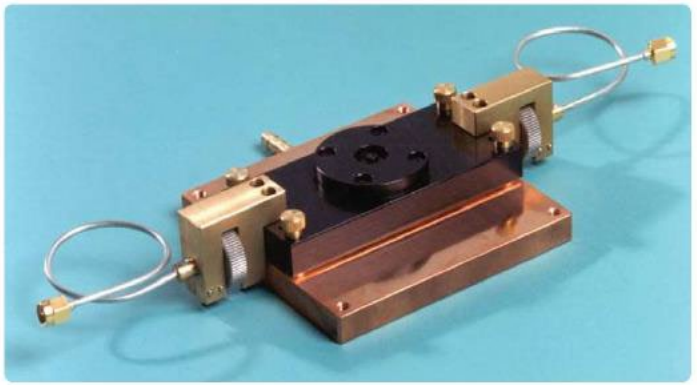
Microstrip

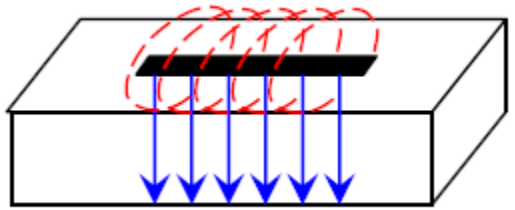


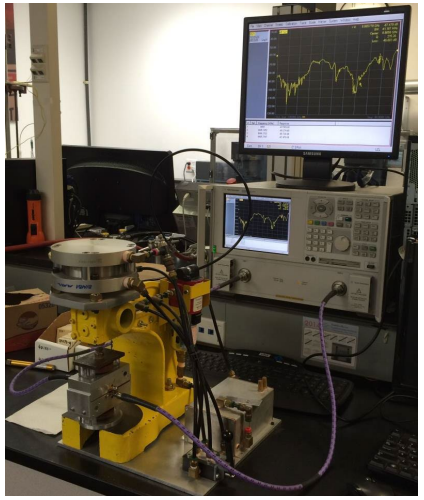
Stripline

Dk and PCB (composite) Materials









Material Ratings:
Data Sheet Values
Different Test Methods
Field Orientation
Stripline X-Band,
Bereskin Stripline,
Split post dielectric resonator

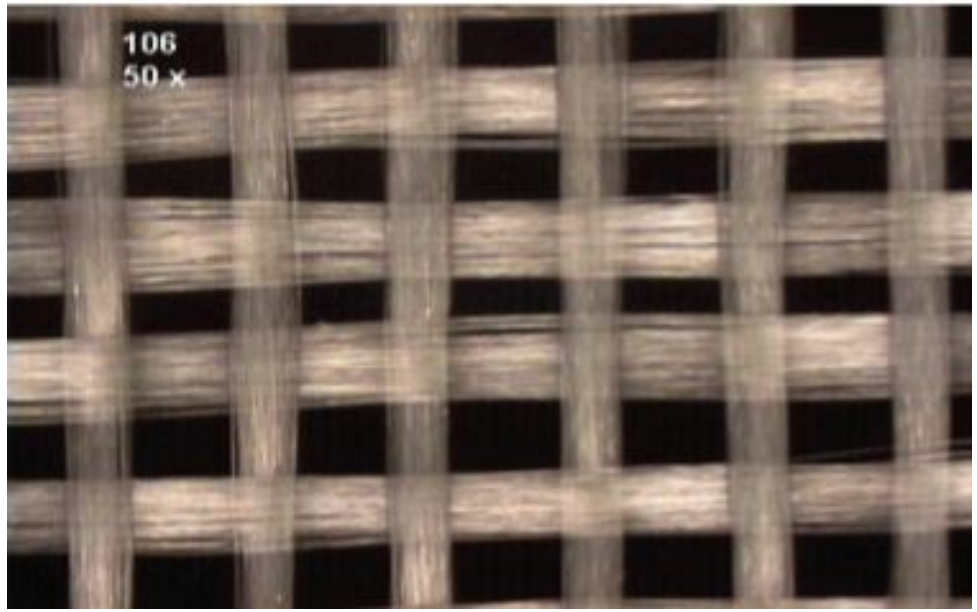
Material Make-up:
Fabric Type
Fabric Weave
Glass to resin ratio
Micro Dk Effects

Impact on the Design:
Impedance
Calculators
Speed/Frequency
PCB shop realities

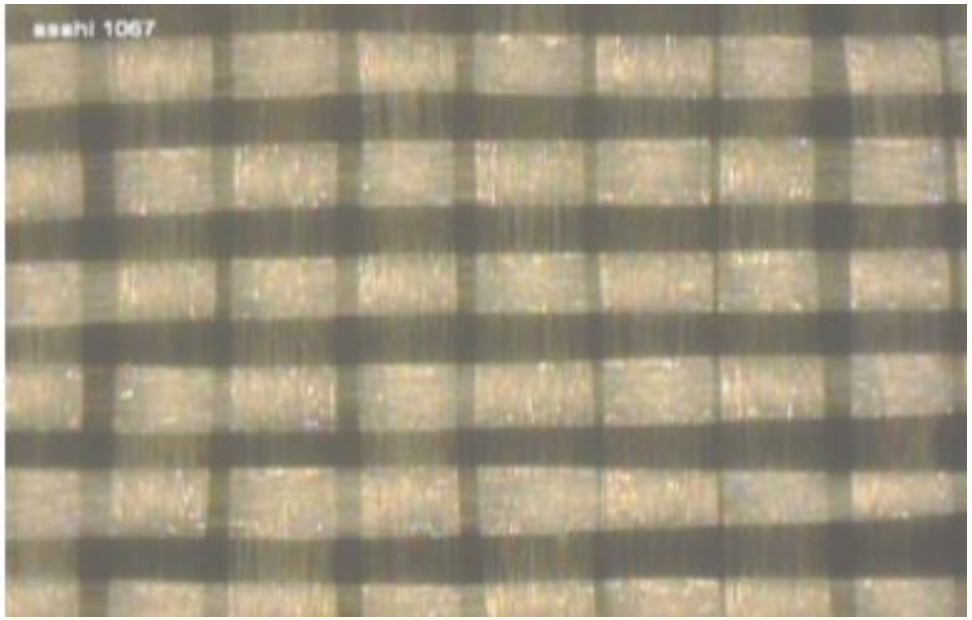
PCB materials are composites and have a combination of properties

“Why does the same material have different Dk?”

- Glass to resin Ratio.
- Copper roughness (not really changing the Dk, but changes capacitance).
- Micro Dk effects along the transmission line.



106 glass



1067 glass

Spread glass prepregs and laminates have a more uniform composition and therefore Dk

Some Examples, Dk and Df Charts (@ 10GHz)

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Glass Style	% Resin	Thickness (inch)	Dk	Df
1x 1067	65.0	.0020	3.74	.0280
1x 3313	51.0	.0035	4.03	.0230
1x 1080	58.0	.0025	3.88	.0260
2x 1080	58.0	.0050	3.88	.0260
1x 7628	44.0	.0075	4.19	0.021

FR-4

Glass Style	% Resin	Thickness (inch)	Dk	Df
1x 1067	72.0	.0025	3.45	.0058
1x 3313	52.0	.0035	3.89	.0060
1x 1080	66.0	.0030	3.57	.0059
2x 1080	66.0	.0060	3.57	.0059
3x 7628	42.5	.0210	4.14	.0061

Mid Dk/Df

Glass Style	% Resin	Thickness (inch)	Dk	Df
1x 1067	70.0	.0020	3.05	.0017
1x 3313	59.5	.0040	3.24	.0022
1x 1078	67.5	.0030	3.09	.0018
2x 1078	67.5	.0030	3.09	.0018
4x 2116	59.0	.0200	3.25	0.022

Low Dk/Df

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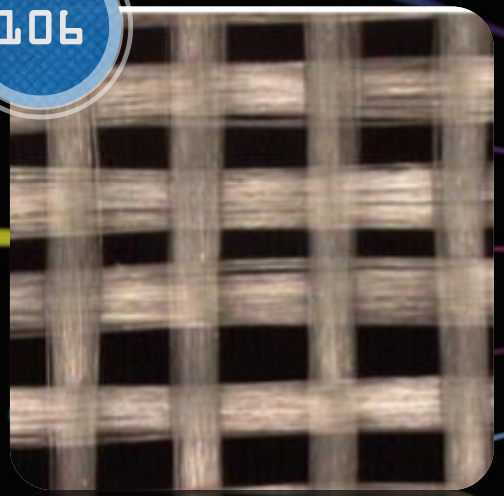
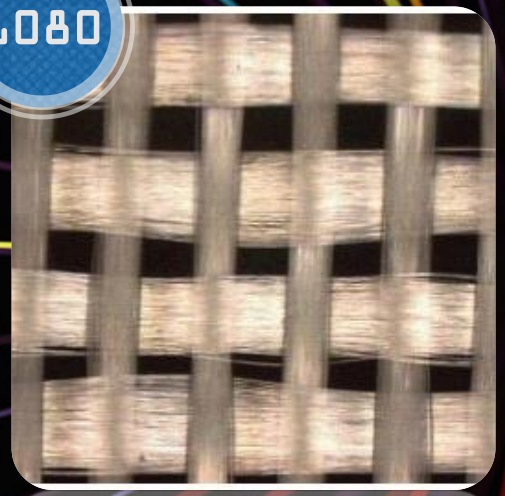
Fiberglass Standard Weave

106



- About 2.0 mils
- Great for fill of heavy coppers.
- Least dimensionally stable.

1080



- About 2.5 mils
- Good for fill.

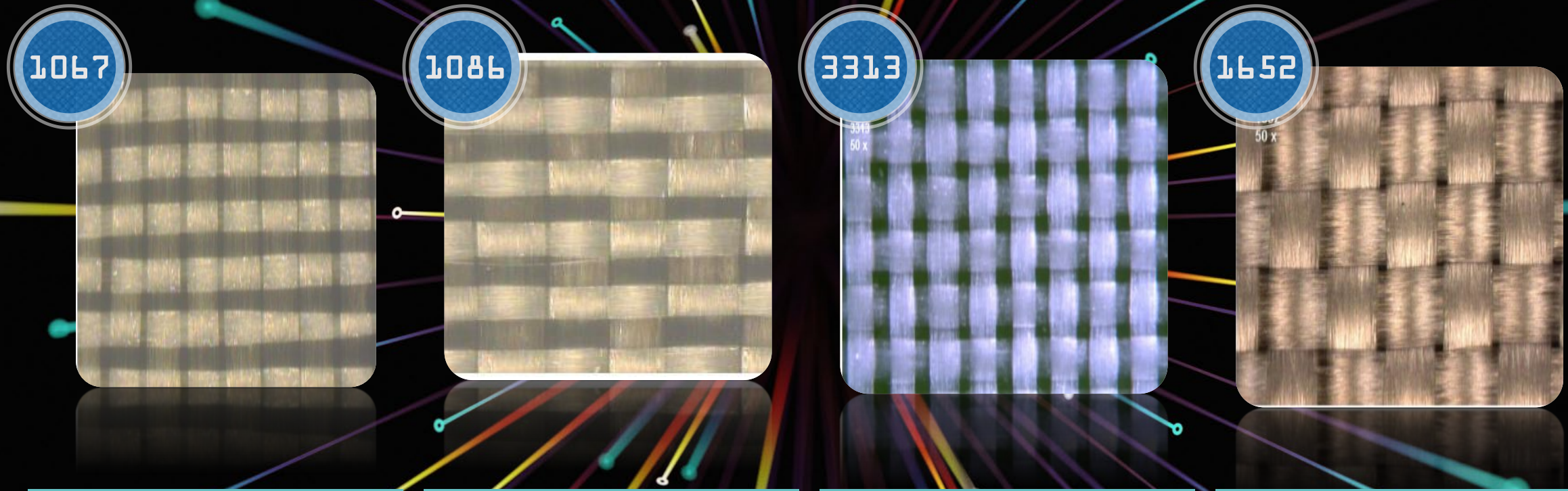
2113

- 3.0 to 3.5 mils
- Some fill properties
- Good stability

7628

- 7.0 to 8.0 mils
- Good for building thickness.
- Best for dimensional stability.

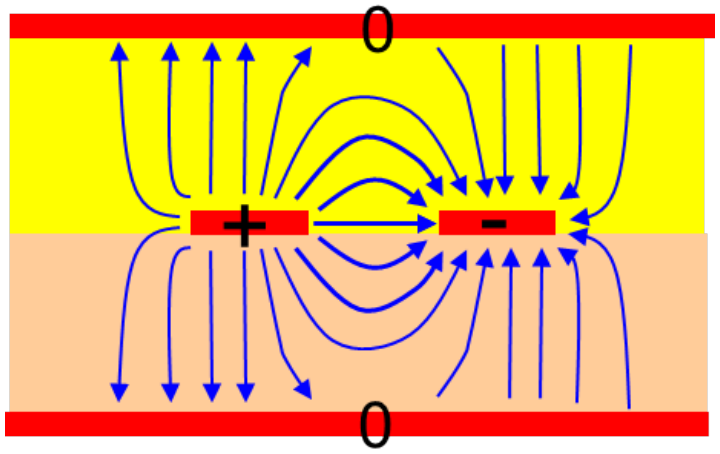
Fiberglass Spread Weave



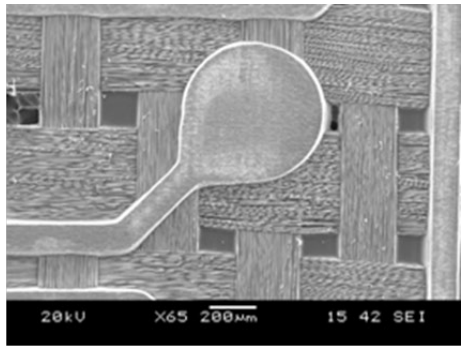
1067	1086	3313	1652
• About 2.0 mils • Great for thickness control • Good for laser drilling • Low signal skew • Not good for filling	• About 3.0 Mils • Great for thickness control • Good for laser drilling • Low signal skew • Not good for filling	• 3.0 to 4.0 mils • Also low skew • Great for thickness control	• 5.0 to 6.0 mils • Also low skew • Great for thickness control

Spread Glass for Differential Pairs

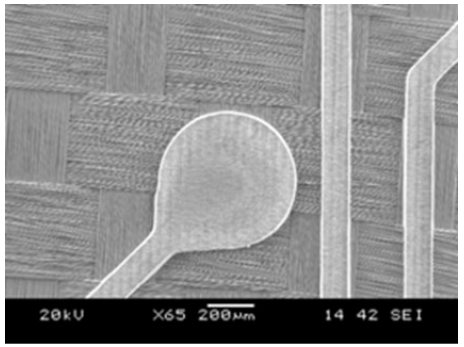
- Reduces micro Dk effects
- Reduces signal skew
- Much better for cost and fabrication than rotating board on panel.



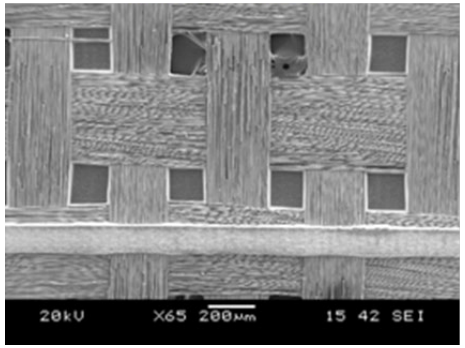
Differential Stripline

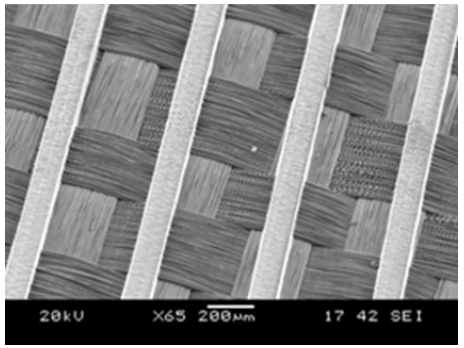


glass cloth 1080



glass cloth 1086MS





1080 vs 1086 with surface resin removed

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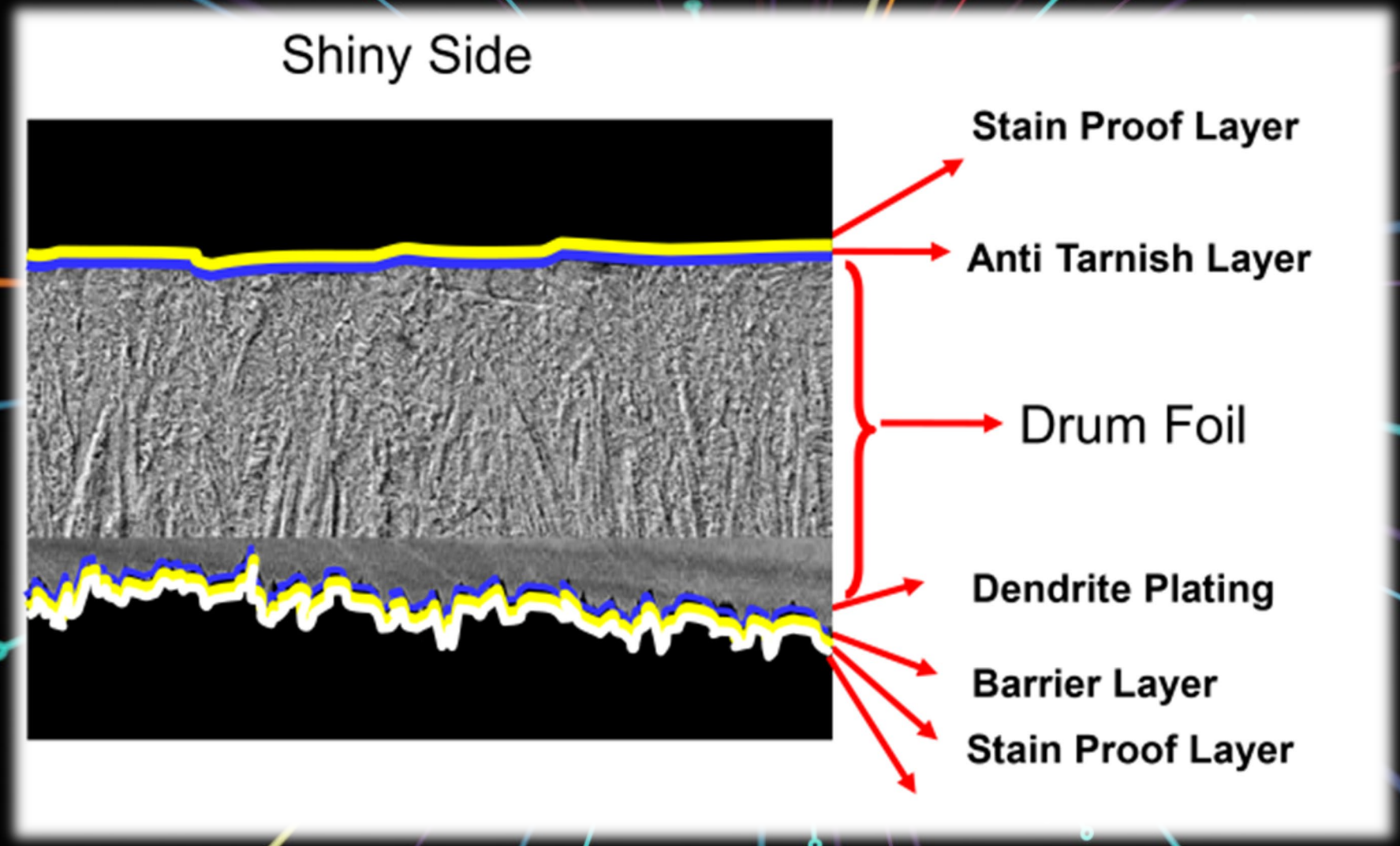
Copper Foil for PCB



Copper Foil Acronyms

- ED – Standard Shiny Copper
- HP – High Performance Foil with extra tooth for high peels*
- HTE– High Tensile of Elongation, Standard Shiny Copper
- DSTF ® – Drum Side Treated Foil*
- RTF – Reverse Treated Foil
- VLP – Very Low Profile
- e-VLP – Extra(?) Very Low Profile*
- H-VLP – H (Hyper) Very Low Profile*
- VLP-2 – Isola's designation for very low profile copper

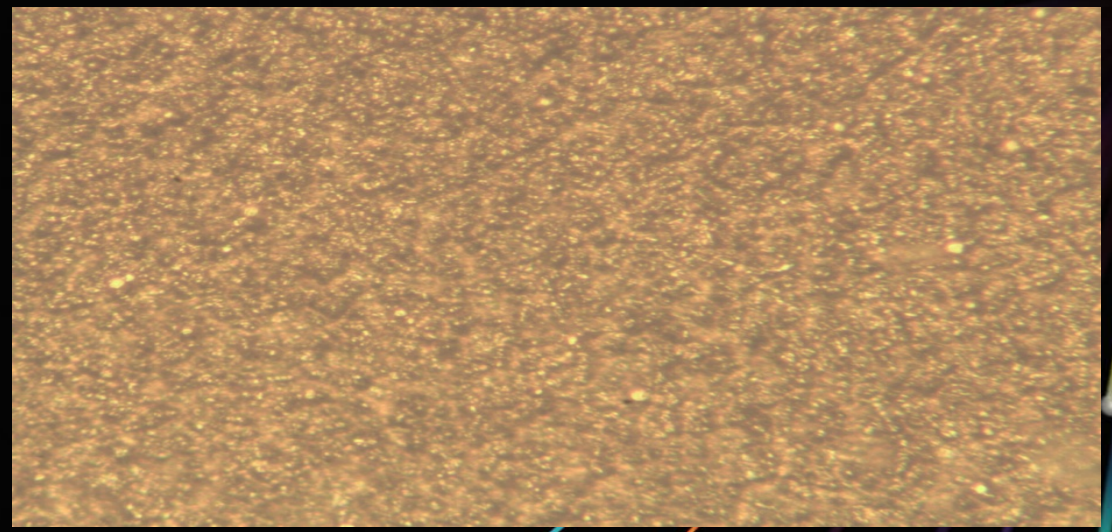
* Not IPC Designations

Profile Thickness Ranges

- Std – Rz~=10 microns
- RTF – Rz~=7 microns
- VLP – Rz~=5 microns
- EVLP (HVLP) – Rz~=3 microns
  - VLP-2 (2 micron)
  - VLP-1 (1 micron)

Copper Foils

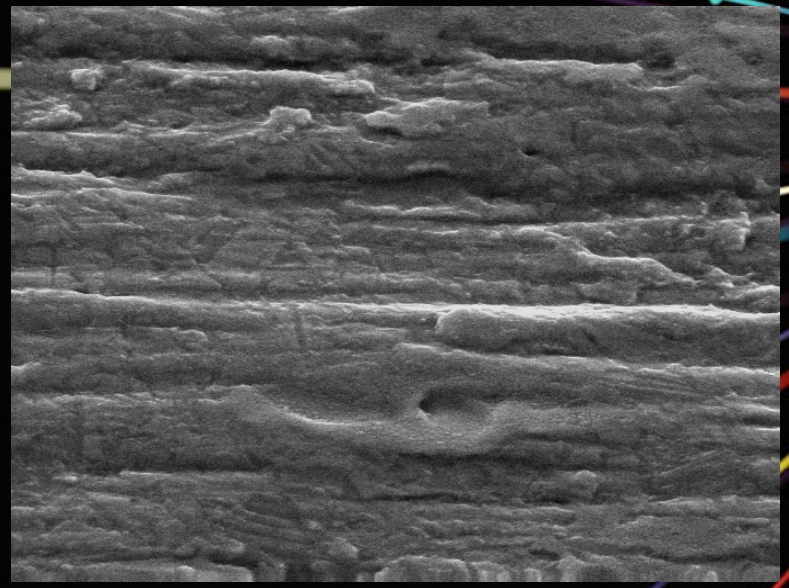
- ED (RTF)



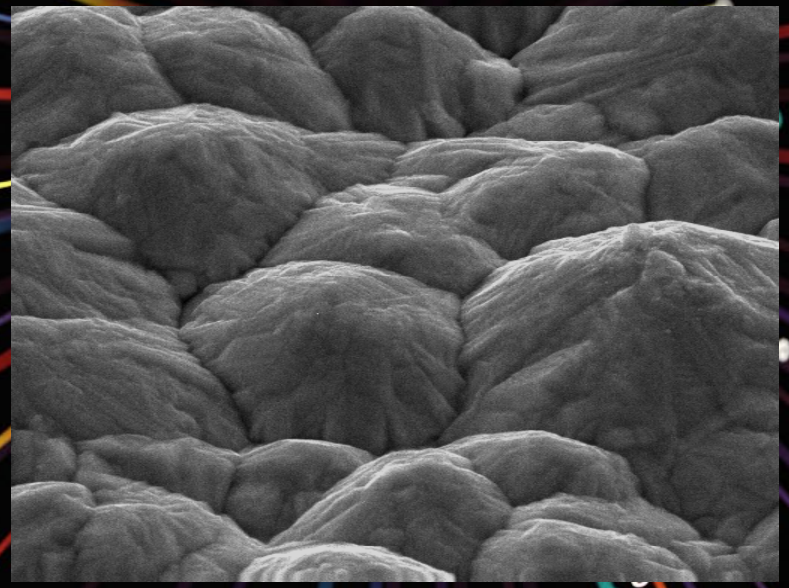
- RA

Copper Foils
SEMs @ 5000X

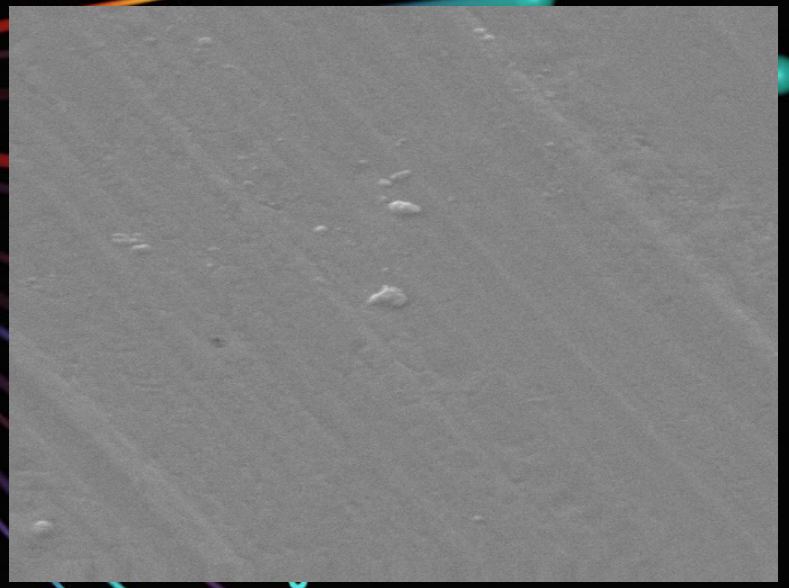
- **ED or Shiny Foil**



Reverse Treat Foil (RTF)



- **Rolled & Annealed Foil**

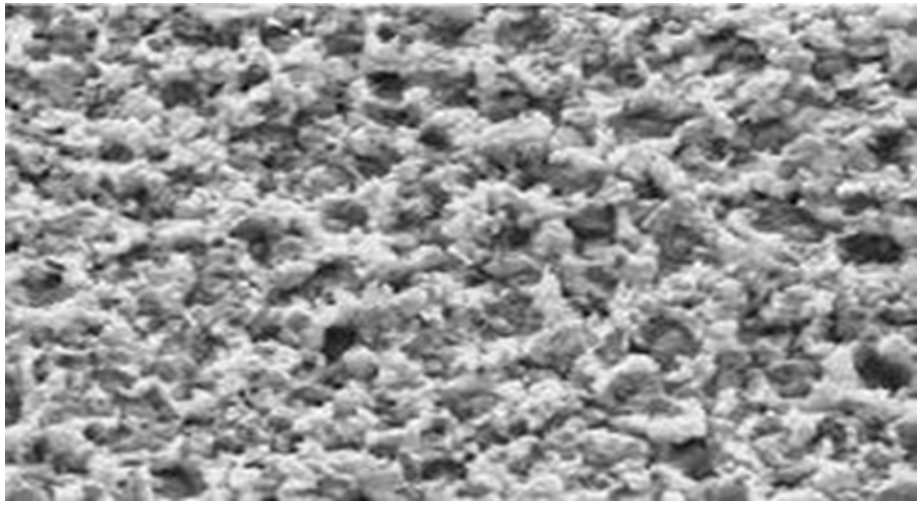


Processes that treat copper in PCB Fab

- Copper clean/prep for Photoresist Adhesion
  - Acid Clean
  - Microetch
  - Hand pumice
  - Mechanical scrub (machine)
- Bond Treatment
  - Hand pumice
  - Mechanical scrub
  - Microetch
  - **Alternative Oxide – Most common**
  - Brown Oxide (reduced) – Old process

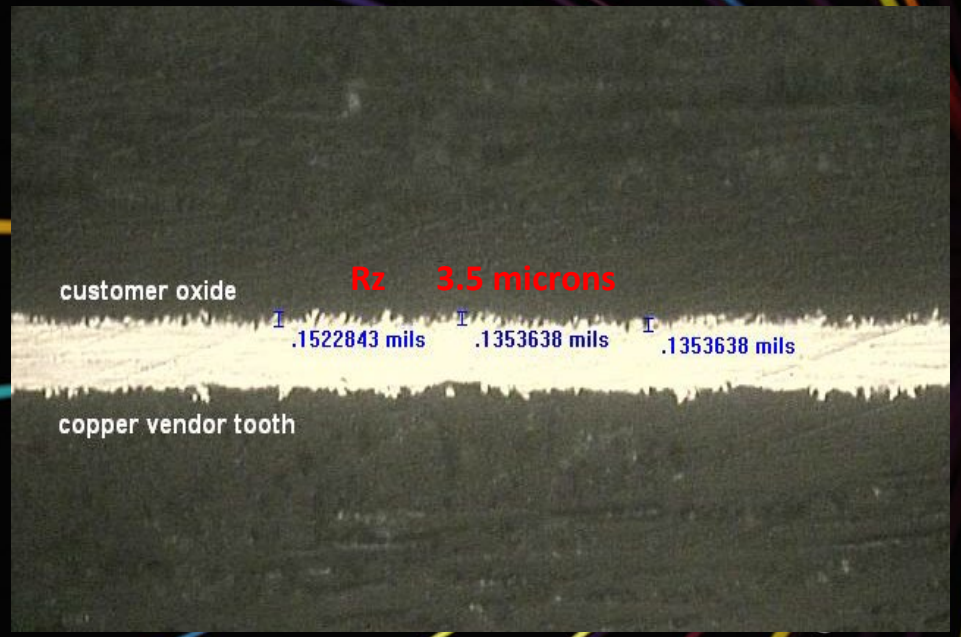
What is Alternative Oxide?

- A bond treatment was developed that contains both an “inter-granular’ etch, and organic complexing agent that reacts with copper to form a brown surface coat.
- It is an alternative to Black/Brown oxide as a bond treatment for copper foil in printed circuit boards.
- It can produce high peels, does not suffer from “pink ring” and is easy to conveyorize. It has become the most popular bond treatment method.
- The main adhesion mechanism is from roughening of the copper surface. It does this by etching the grain boundaries faster than the surface.
- Excessive roughness will increase signal loss.
- Grain boundaries can cause foil cracks in flex if they are too deep.



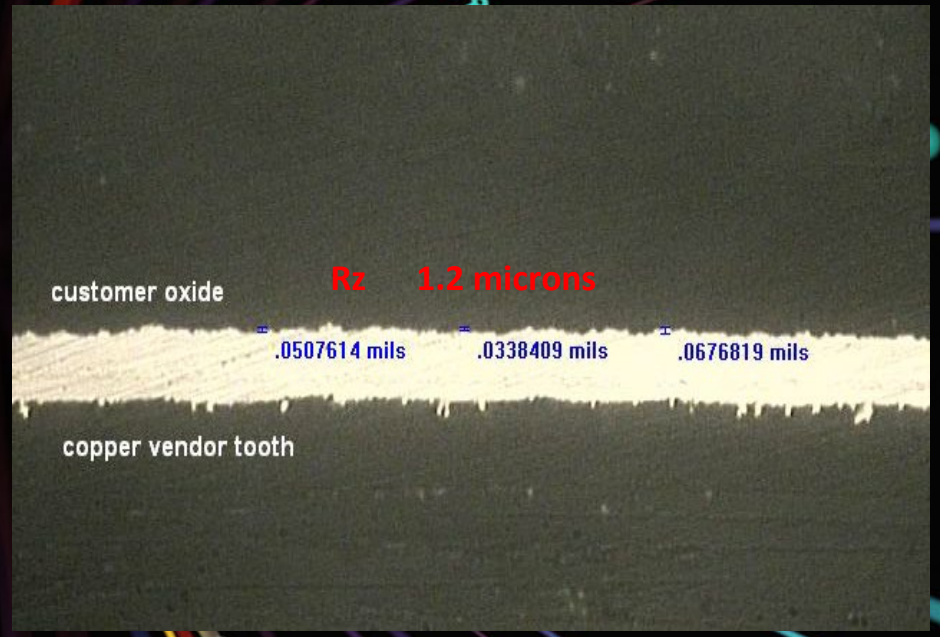
Effect of Copper Bond Treatment

Heavy Alt. Oxide



High signal Loss

Lighter Alt. Oxide



Lower signal Loss

Sometimes less is more

1. PCB Material Overview
2. What is the Dielectric Constant of a material?
3. PCB building blocks: Prepregs
4. Copper foil for making circuits
5. Bring it together for best signal performance

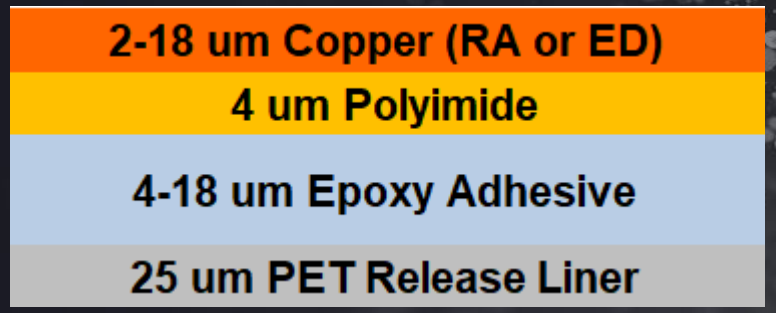
Work with the Fabricator

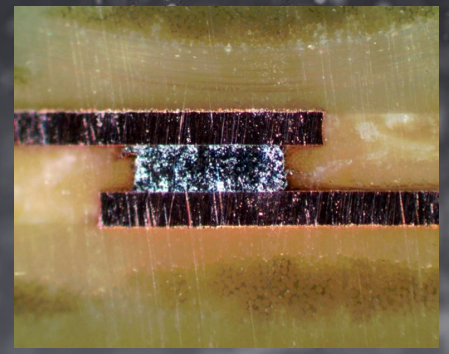
- What does my design need?
  - Signal performance, HSD or RF?
  - Thermal? Mechanical?
  - Density?
  - Flex?
- Material Selection
  - Dk, Df, Cost, Availability, Hybrid, etc.
  - Spread Glass Options
  - What kind of copper foil? RTF, HVLP, etc.
- PCB Fab
  - Bond Treatment
  - Impedance control
  - Surface finish
  - Soldermask

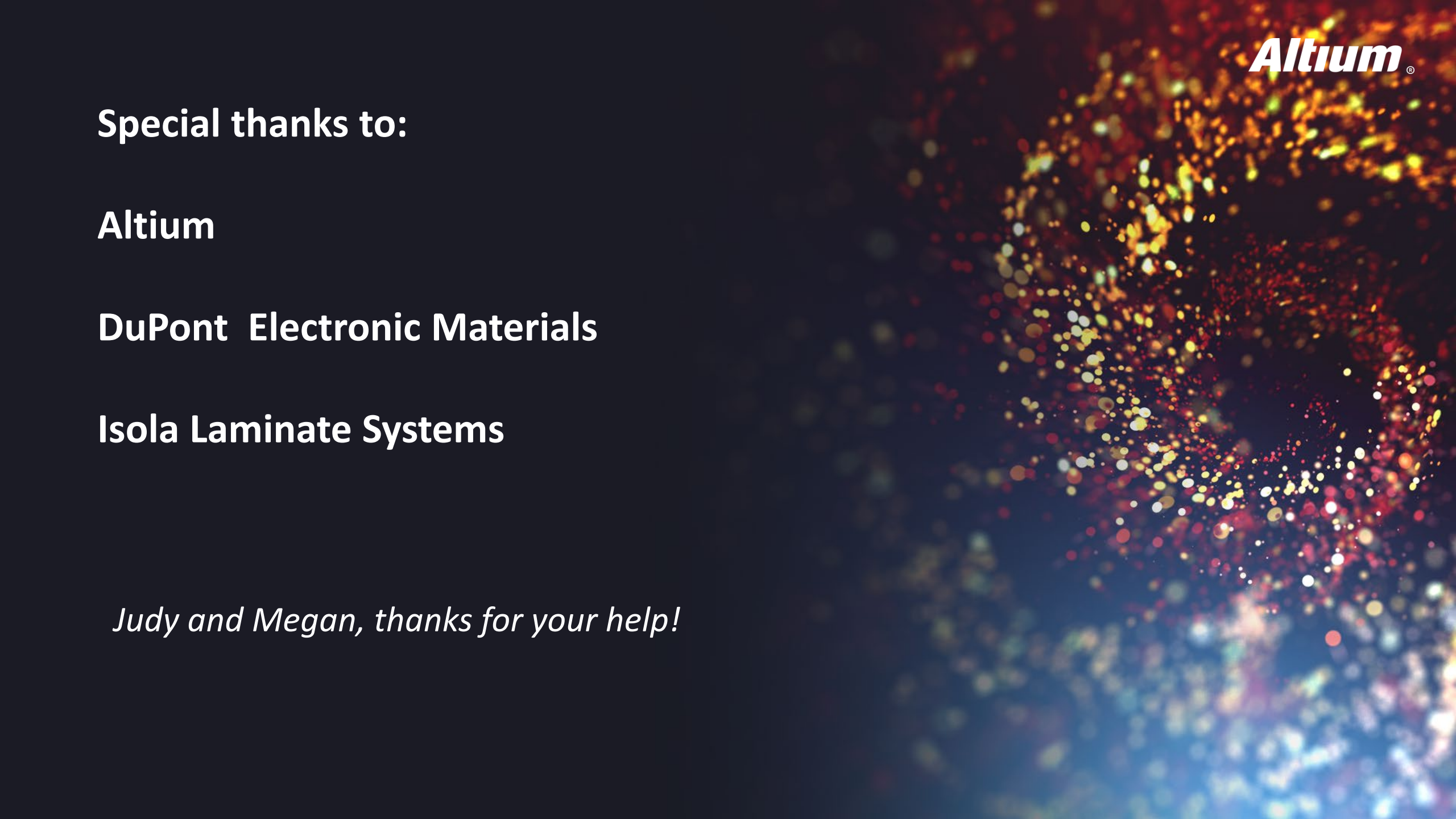
Altium®

More PCB Technology:

- Embedded components
- Resin coated copper
- Embedded coax
- Molded Circuits
- Paste interconnects







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Altium

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