Presented by Royal Flex Circuits and Insulectro

Flexible PCB’s

Royal Flex Circuits: Bob Meyer – Larry Ybarra

And Insulectro: Chris Hunrath

Royal Flex Circuits

Quick Turn PCB Flex & Rigid-Flex Specialist:

Over the last 30 years, Royal Flex Circuits has become the leader in quick-turn, high-tech PCB manufacturing – with no minimum order quantity. Using the latest technology and cutting-edge equipment, we are building the Factory of the Future with the capability to manufacture from the most basic to todays industry leading technology.

Royal Circuits Group

Royal Flex Circuits, in Santa Fe Springs, CA. is part ot the Royal Circuits Group, a highly recognized PCB company with manufacturing facilities in both Northern and Southern California. Royal Flex Circuits moved into a new, custom build production facility a little over a year ago, featuring the latest machinery, hardware and production methods.

Flex, Rigid-Flex, Rigid and Assembly

Santa Fe Springs, CA

Quick turn, specialty applications

Rigid

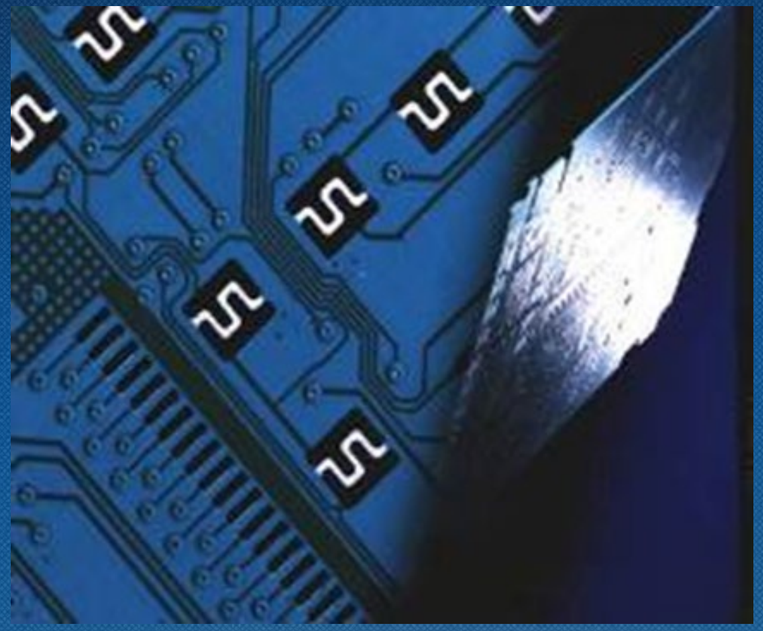
Hollister, CA

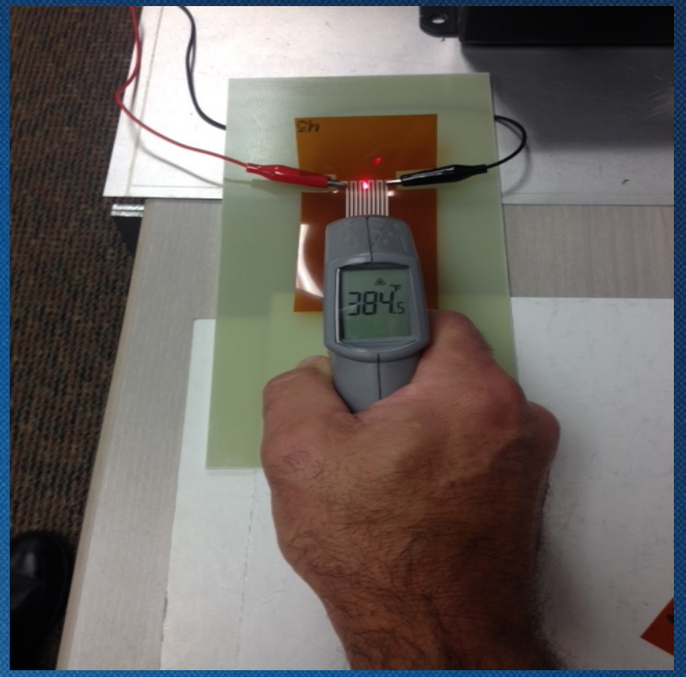
Quick turn, turn key, FR4, Polyimide, HSD and RF. Heavy copper (> 3.0 oz). Proto to production.

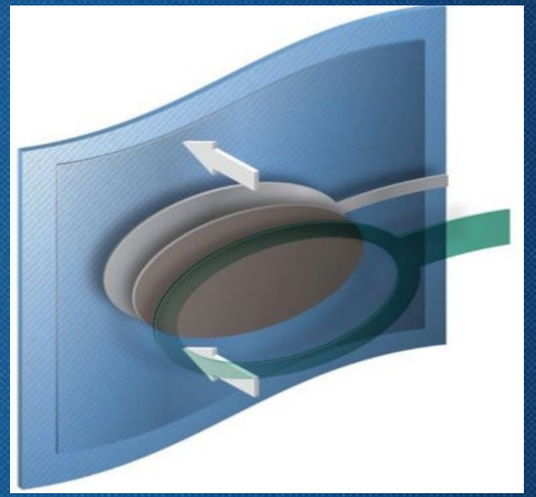
Insulectro: Electronic Materials

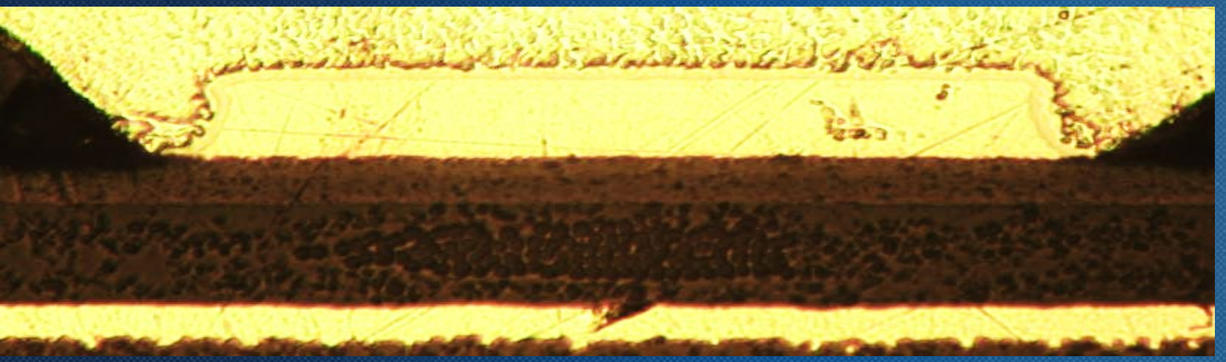
- Offer a wide range of PCB materials from premier suppliers.
  - Isola, DuPont, LCOA, CAC, Pacothane, Oak Mitsui, JX Nippon
- Maintain the critical mass required to provide better access to products and technical support for the electronics industry.
  - Provide Local Inventory
    - Customers access material in hours
  - On-site technical support
- ACT! Accomplish Change Together
  - Support fabricators with their customers
  - Provide support for proper material selection

Materials for many technology Applications

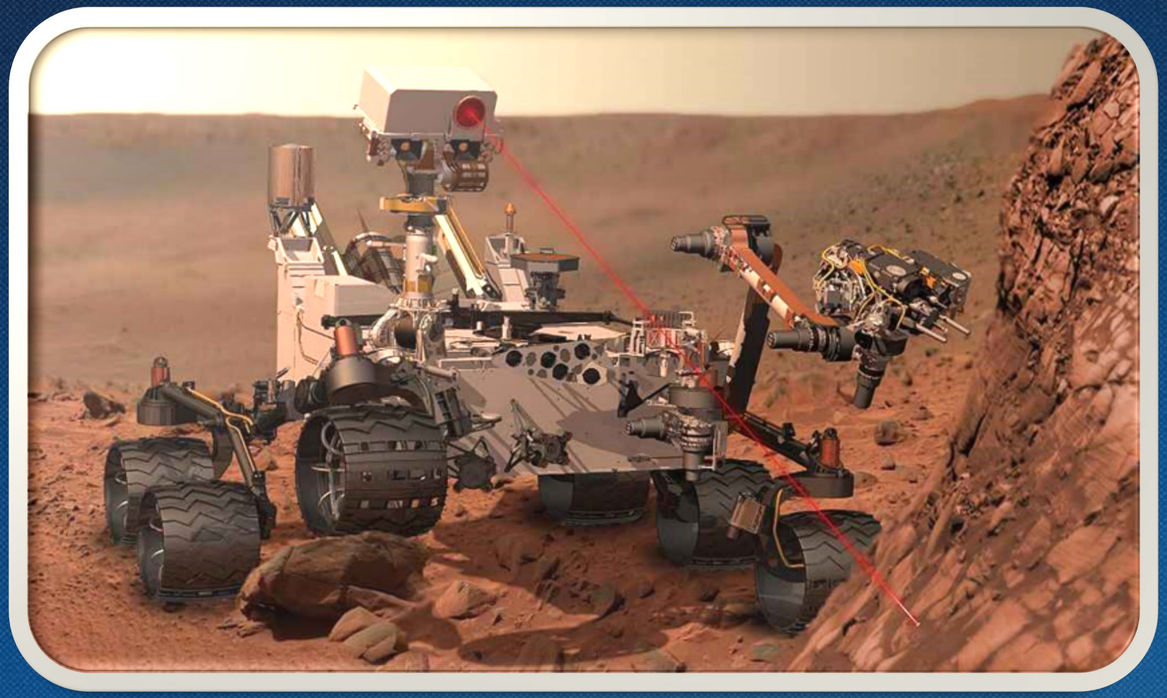


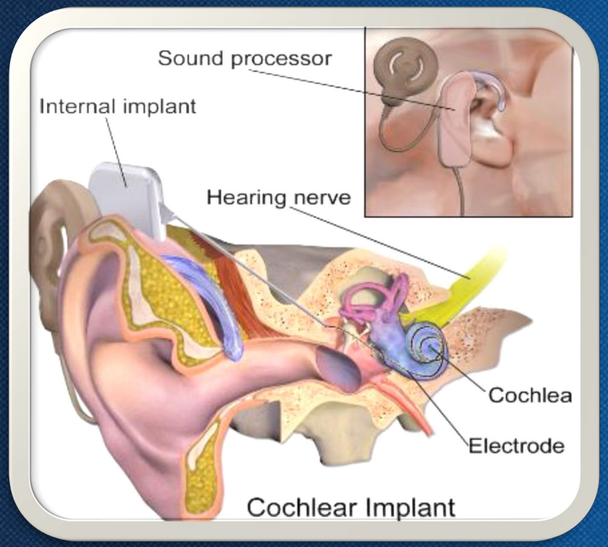




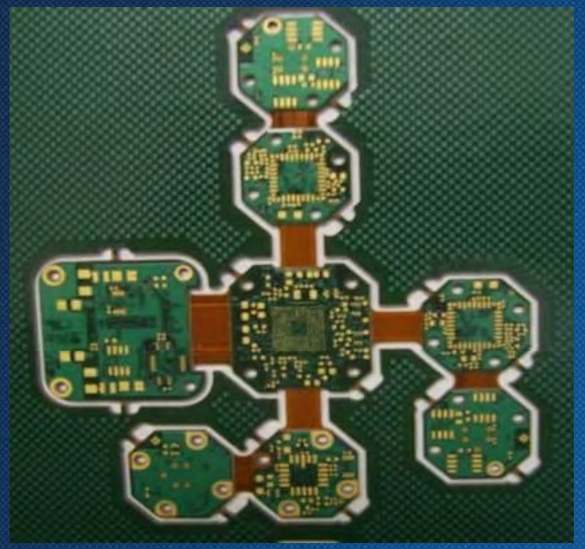


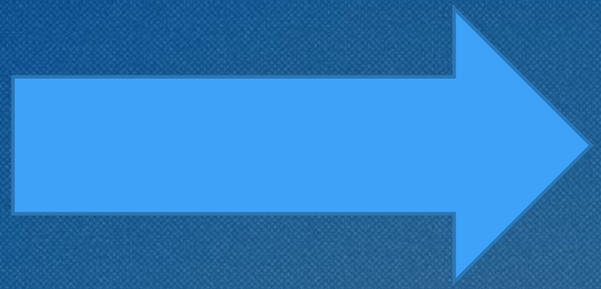
Why Flex?

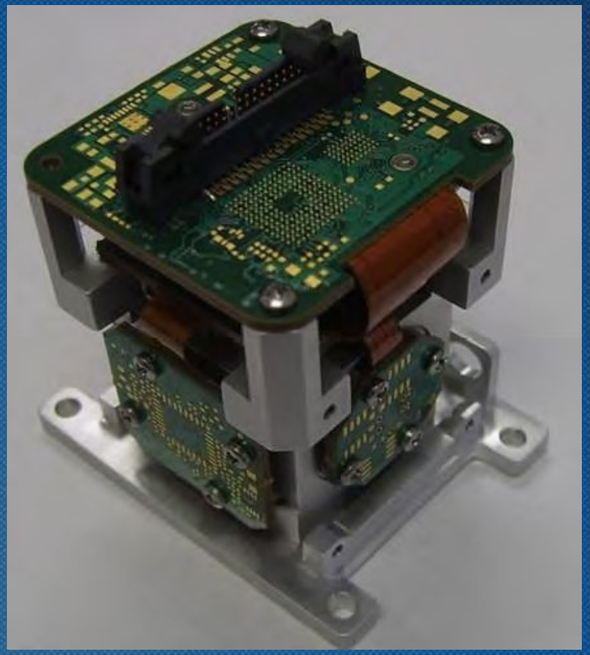



Sound processor
Internal implant
Hearing nerve
Cochlea
Electrode
Cochlear Implant

Bend to Install



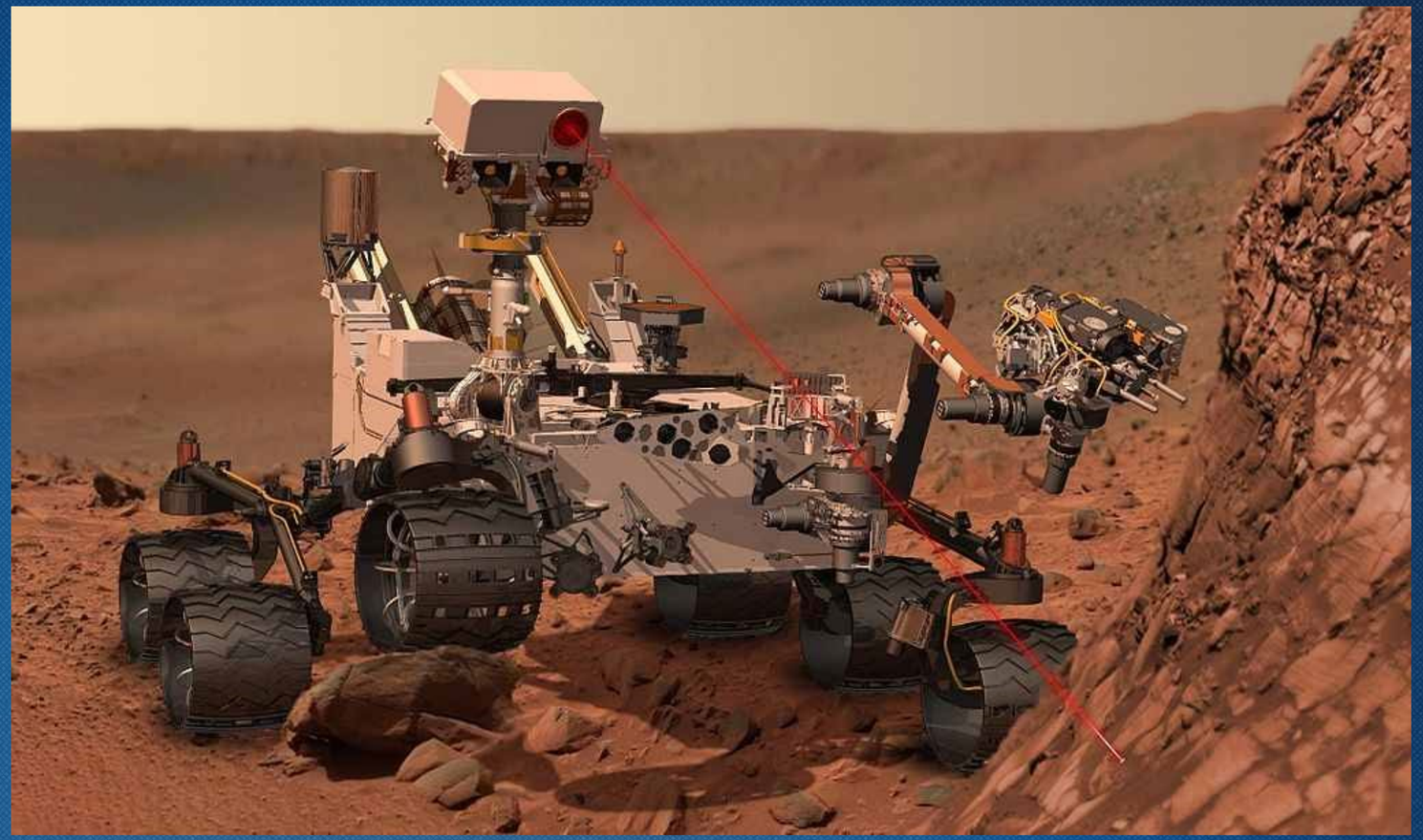




Pyralux® and Kapton®

- Aerospace
- Outer space
- Medical
- Exploration

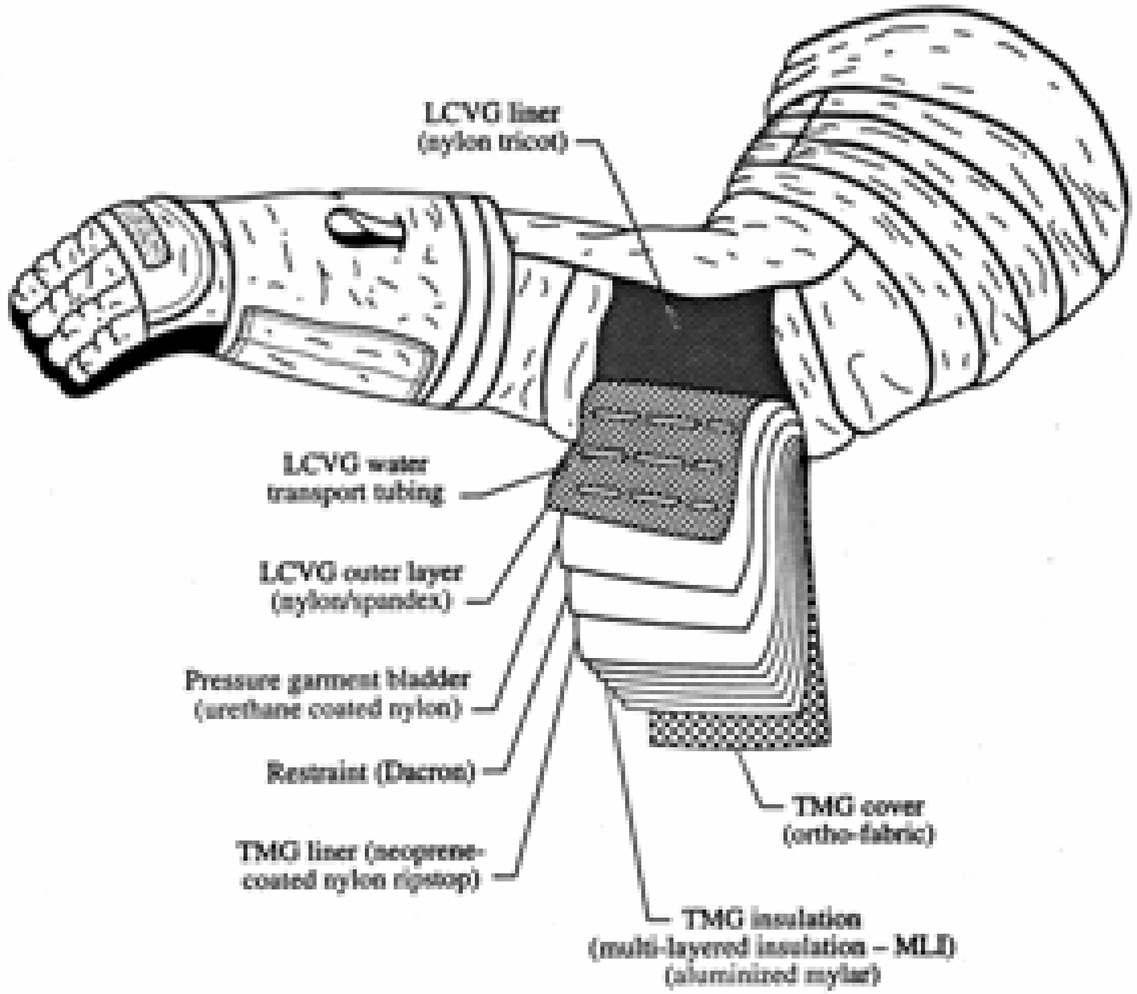
Mars Rover



Kapton®

Apollo/Skylab A7L suit

- Kapton was first produced in the 60’s
- Once used in space suits as a micrometeoriod barrier
- Still extensively Used in space
- LF adhesive was first produced around 1976
- Basis of many flexible PCB’s
- More applications in Rigid PCB



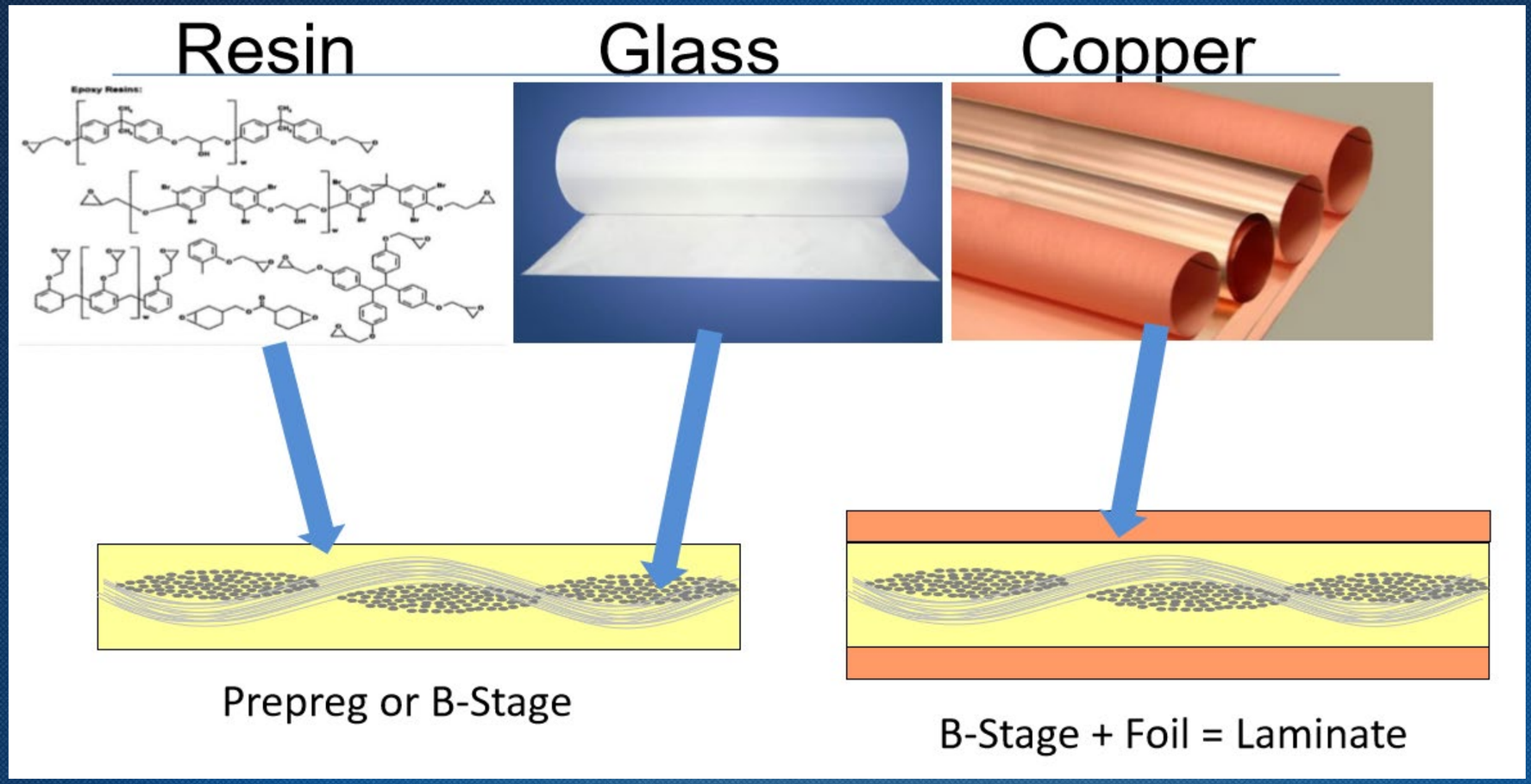
Cross section of material layup used for fabric for the arms and legs of the spacesuit.

Design Success

- PCB’s are no longer simple replacements for wires.
- They are an integral part of the design.
- You don’t need to be material science experts.
- Many of the new materials bring technology and/or performance advantages.
- We are here to help.

PCB Rigid Laminates

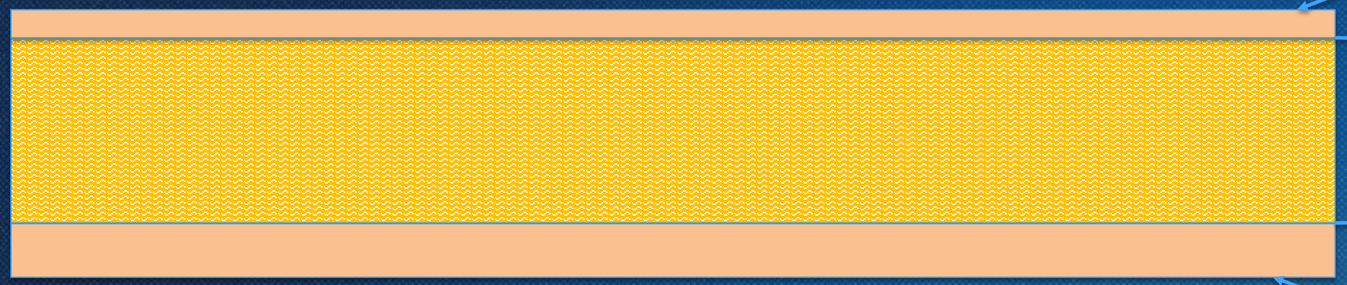
The Basics: PCB materials are COMPOSITES



Each component plays a role in providing the right properties for the design.

Common Rigid Core Construction

Signal Circuitry

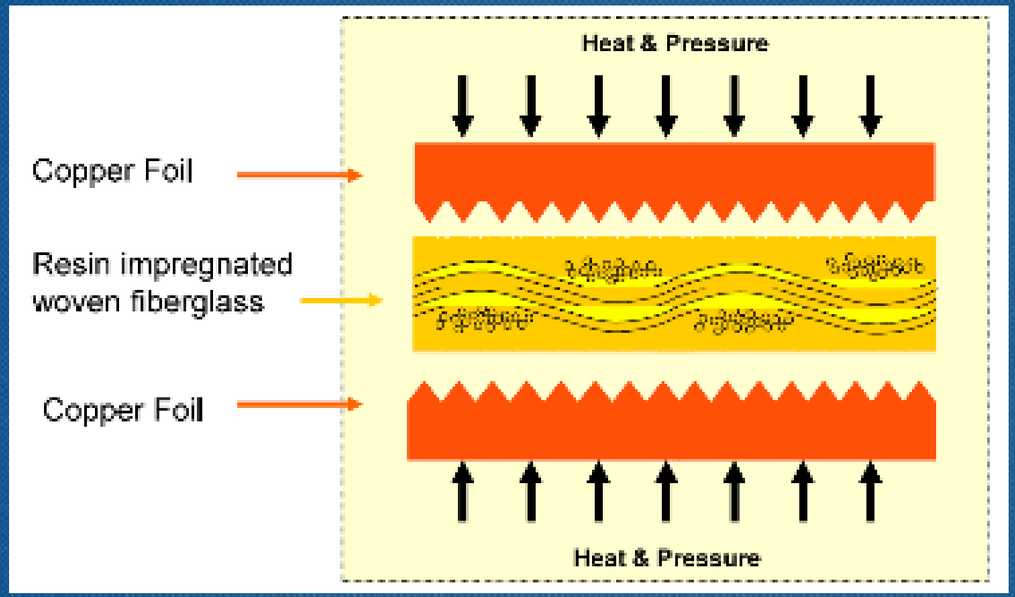


½ oz copper foil

Core dielectric
Typically 3.0 to 8.0 mils

1 oz copper foil

Plane



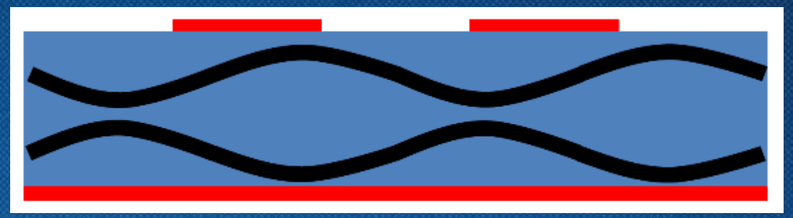
Reinforced versus Unreinforced Laminates

- Unreinforced

Thick (200 um) - Niche
-Excellent performance/reliability
-Expensive to manufacture

Thin (50 um) - Common
-Excellent performance/reliability
-Less expensive to manufacture

- Glass Reinforced

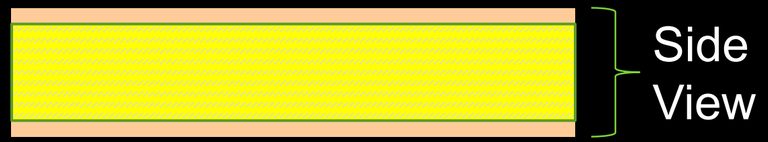


Thick (200 um) - Common
-Excellent performance/reliability
-Less expensive to manufacture

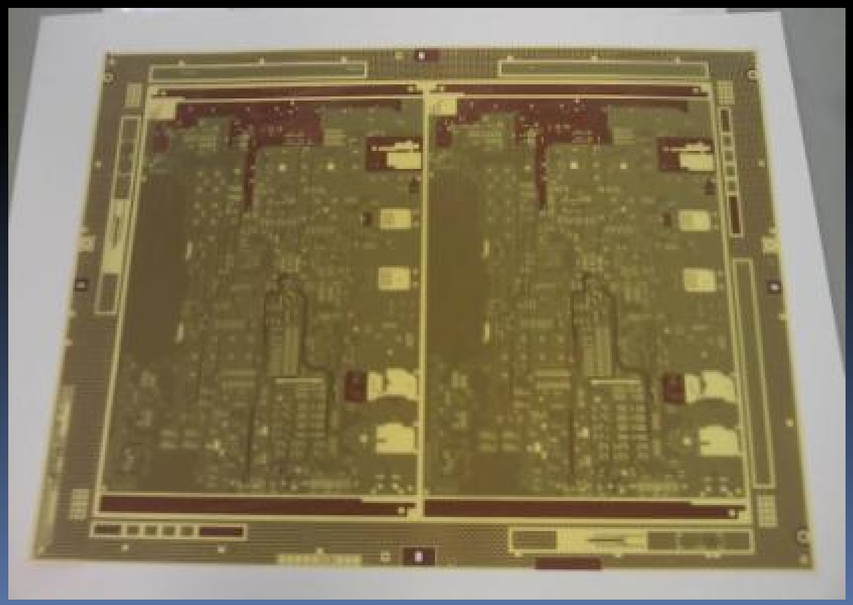
Thin (50 um) - Niche
-Less performance/reliability
CAF; Pad Cratering; Etch Defects
-Same or more expensive to manufacture

What Royal Flex Circuits does with the material

Blank layer , copper is on both sides with laminate (dielectric) in the middle.



After etching the copper in a pattern, the laminate in the middle is revealed. The copper is coated with a brown bond treatment.



Some Important PROPERTIES

GLASS TRANSITION TEMPERATURE

Tg

DECOMPOSITION TEMPERATURE

Td

COEFFICIENT OF THERMAL EXPANSION

DIELECTRIC CONSTANT

Dk

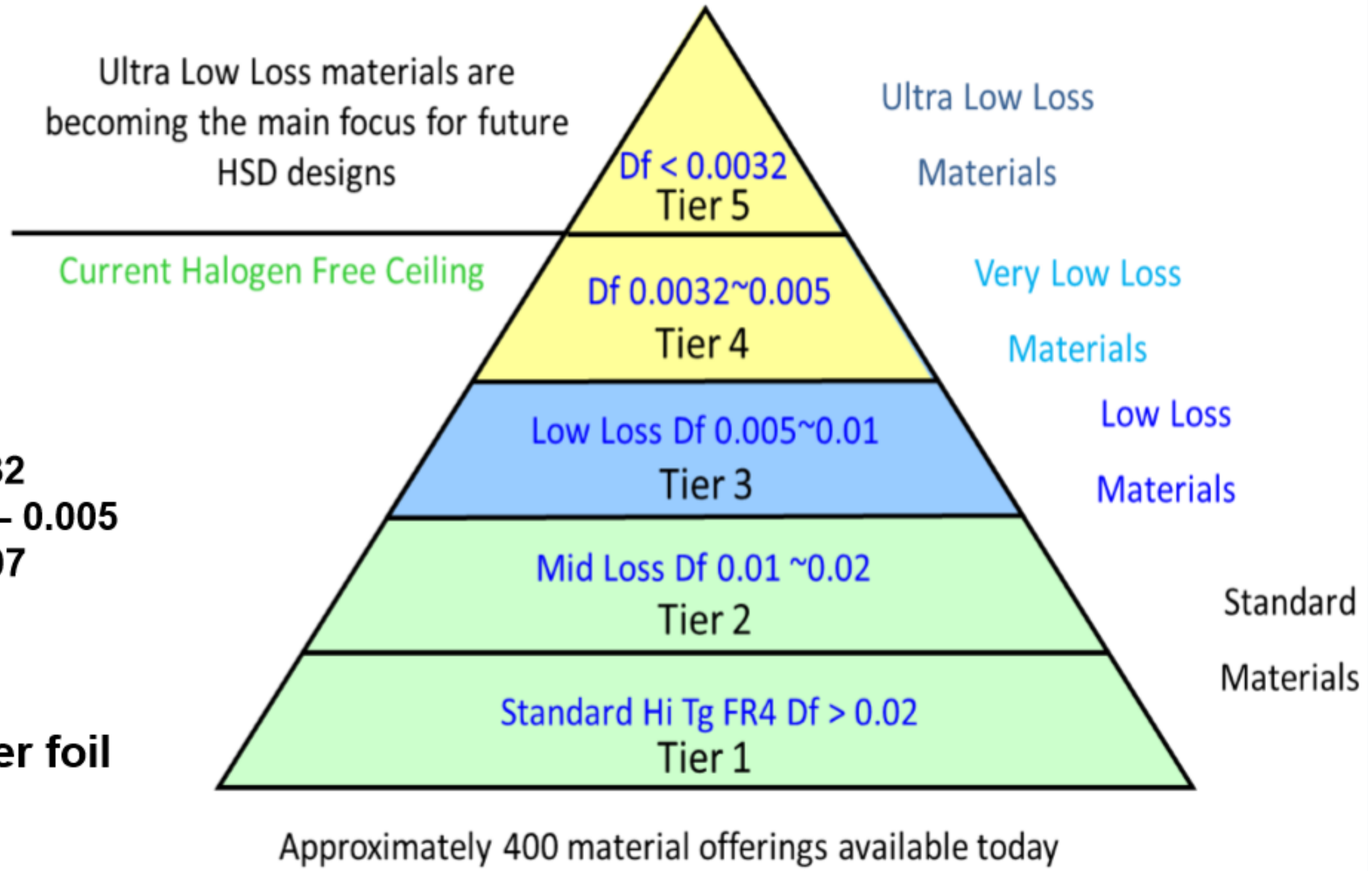
DISSIPATION FACTOR

Df

So Many Materials

Basic Categories

- **Dielectric Constant Dk**
  - **Standard Dk ≥ 4.0**
  - **Mid Dk: 3.5 – 4.0**
  - **Low Dk: 3.0 – 3.5**
  - **Ultra Low: ≤ 3.0**
- **Dissipation Factor Df**
  - **Ultra Low Loss Df ≤ 0.0032**
  - **Very Low Loss Df: 0.032 – 0.005**
  - **Low Loss Df: 0.005 – 0.007**
  - **Mid Loss Df: 0.010 – 0.02**
  - **Standard Df ≥ 0.020**
- **Conductor losses of copper foil**
  - **RTF**
  - **VLP**
  - **NP/ANP**



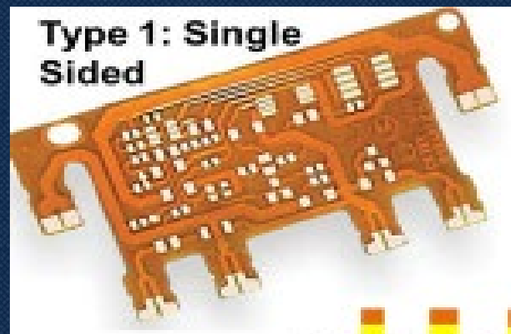
More on this later

Bulk Properties of FPC Dielectric Films

Property	Unit	Method	Kapton® HN	Pyralux® AP	Pyralux® HT Bondfilm	Pyralux® TK	LCP
Thicknesses	mil	–	1 - 5	1 - 6	1-4	2 – 4	1, 2, 4
Dk @ 10 GHz	–	Method 2.5.5.5	3.4	3.2	3.0	2.5	3.0 - 3.1
Df @ 10 GHz	–	Method 2.5.5.5	0.010	0.002 - 0.003	0.003	0.002	0.001 - 0.002
% Moisture uptake	%	Method 2.6.2	2.8	0.8	0.8	0.6	0.04
CTE (x-y axis)	ppm/°C	50 to 250 °C	20	25	25	27	18
CTE (z axis)	ppm/°C	50 to 250 °C	115	90	90	102	120
Peel strength	N/mm	IPC-TM650	N/A	2.0 (ED) 1.6 (RA)	N/A	1.2 (RA)	1.0 (ED) 0.4 (RA)
Tg	°C	DMA	360 - 410	220	220	270	–
Tm	°C	DSC	–	–	–	300	280 - 315
Flammability	–	UL94	V-0	V-0	V-0	V-0	V-0

General Flex PCB Types

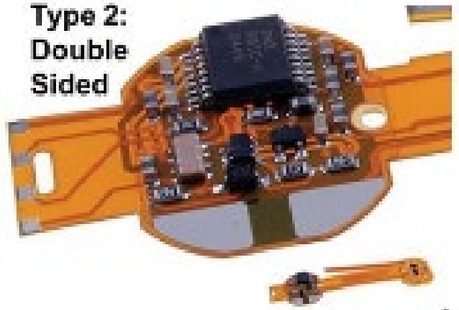
Type 1: Single Sided

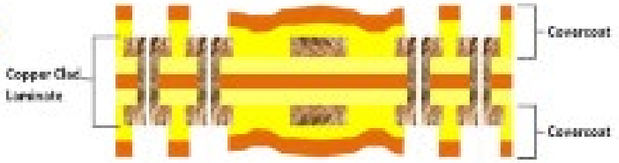


(Crossection View)

B Covercoat (DuPont LF0210)
A Copper Clad Laminate (DuPont AP9121)

Type 2: Double Sided

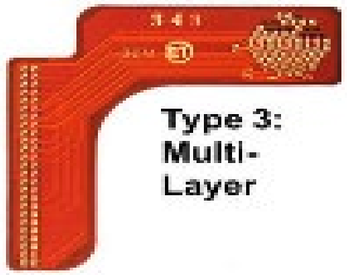




(Crossection View)

B Covercoat (DuPont LF0210)
A Copper Clad Laminate (DuPont LF9111)
B Covercoat (DuPont LF0210)

Type 3: Multi-Layer

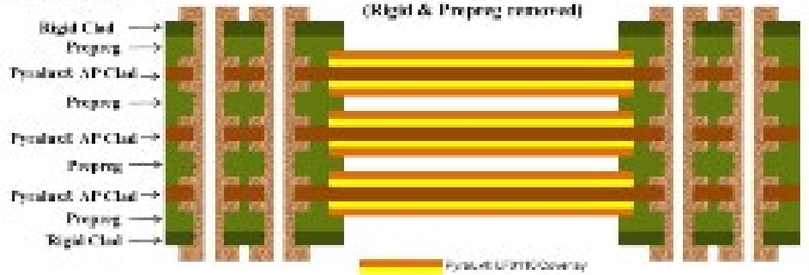


Type 4: Rigid-Flex

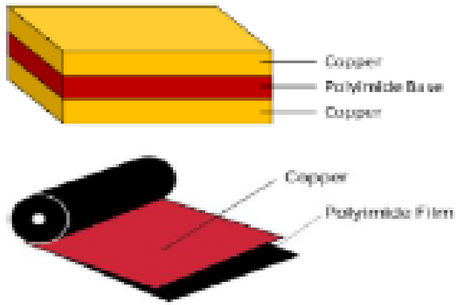
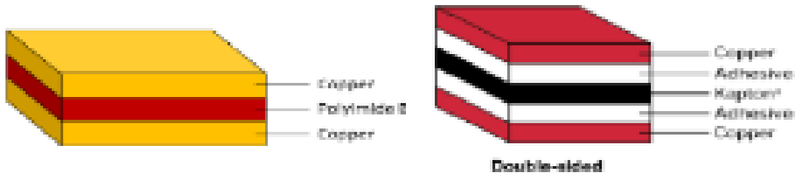
Book-Binder Bent Configuration

Book-Binder Flat Configuration

Rigid Section
Flexible Section
(Rigid & Prepreg removed)
Rigid Section



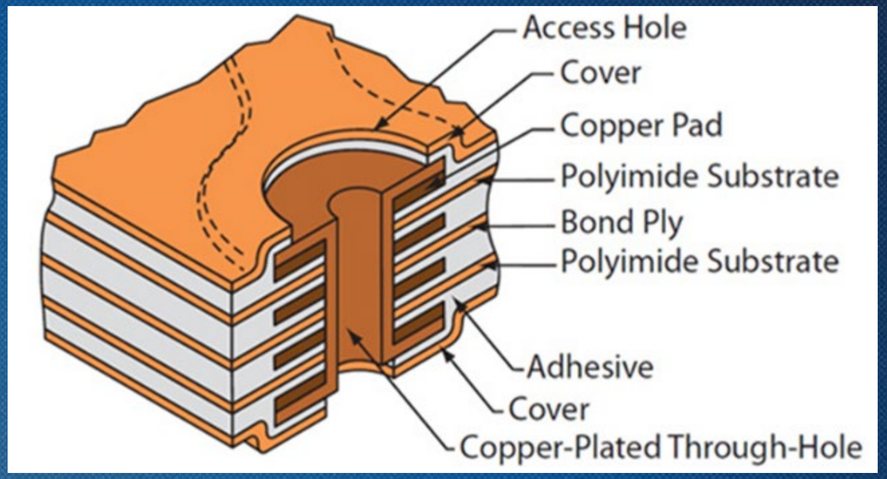
Flex Materials

Term	Description	Products	Examples
Copper Clad - 2 Layer also called; FCCL – Flexible Copper Clad Laminate All-polyimide clad Adhesiveless clad Copper = Layer 1 Polyimide = Layer 2	Copper foil laminated directly to the polyimide base material. Polyimide cast directly onto the copper foil. (Cast on Copper)	Pyralux® AP Pyralux® HT Pyralux® AC	
Copper Clad - 3 Layer also called; FCCL – Flexible Copper Clad Laminate Copper = Layer 1 Adhesive = Layer 2 Polyimide = Layer 3	Copper foil laminated to one or both sides of a adhesive coated polyimide base material.	Pyralux® LF Pyralux® FR	
Single-sided Clad	Copper foil on one side of a flexible dielectric base material.	Pyralux® LF Pyralux® FR Pyralux® AC	
Double-sided Clad	Copper foil on both sides of a flexible dielectric base material.	Pyralux® AP Pyralux® HT Pyralux® LF Pyralux® FR	

Flexible Circuit Materials

Polyimide film is the “backbone” of flexible PCB’s

- Usually Kapton Film, different from rigid polyimide
- Very good high temperature performance
- Very good electrical performance
- Cost goes up dramatically with thickness above 2.0 mils
- Can be used in rigid PCB’s for thin layers; i.e. buried capacitance
- Layers are joined with glass free acrylic or epoxy adhesives



Most flexible copper clads will use RA (rolled annealed) copper foil.

Why and how we choose a Flex Film Components

Impedance (Controlled Impedance)

- Dk (dielectric constant)
- Thickness

Signal Loss (loss tangent/Df dissipation factor)

- Df of resin and glass

Dynamic flex vs Bend to Install

- Bend direction and radius

Circuit Density

Cost and Availability

Cost vs performance to meet your requirements

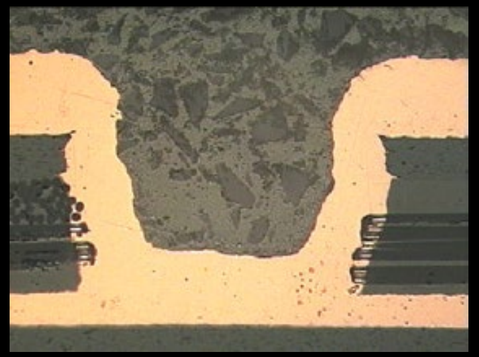
Dk – Dielectric Constant

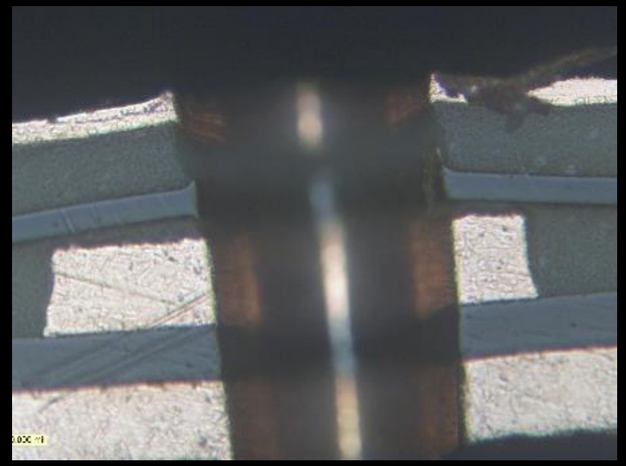
- Used for obtaining proper impedance, signal properties

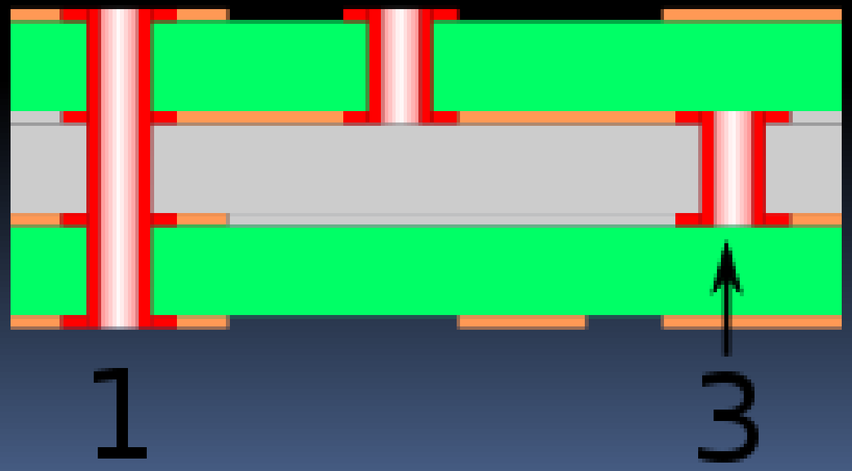
- Often spec’d over a range because exact value will vary even within the same family depending on dielectric thickness and glass to resin ratio.

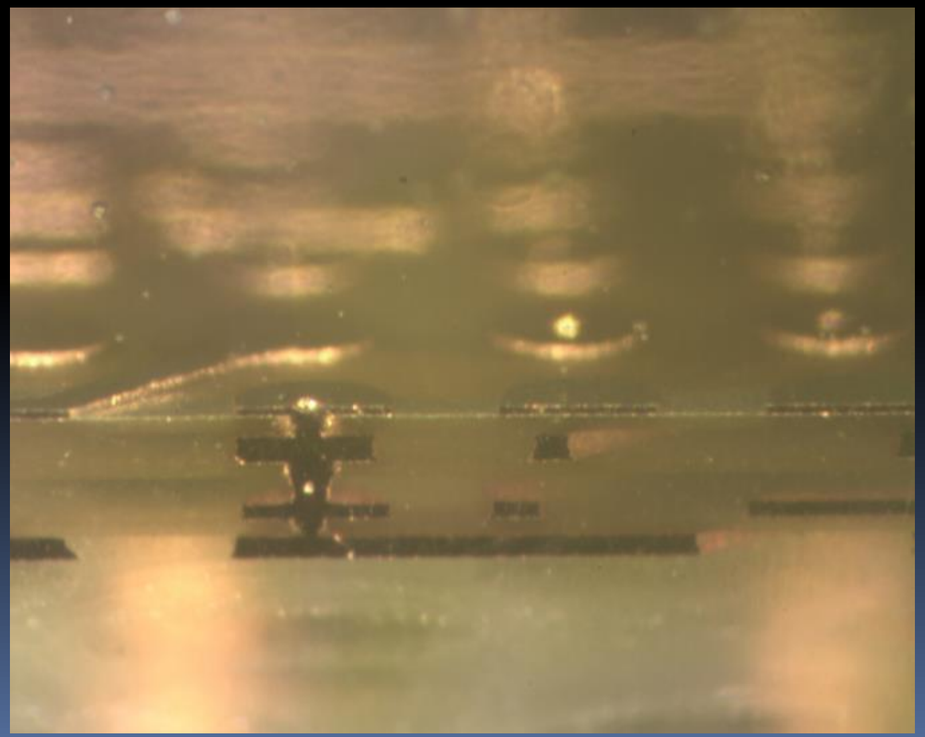
- Also dependent on temperature, moisture and frequency used in the design.

Copper plating brings all of the layers together









More Properties

Dissipation Factor

A material property that characterizes signal loss. Resin, glass and copper foil all play a roll in this.

Moisture Absorption

Usually as a weight percent.
Impacts assembly, Dk and Df

UL Rating

UL-796 covers PWB

UL-94 covers flame rating

UL 94-V0 is most common

Other: V1, V2, HB, etc.

Some materials from the same supplier are in the same UL family

Time to Delamination

Test to determine thermal robustness. Sample are heated and kept hot until failure.

Combination of the following;

- Material loss (Df)
- Conductor (Copper Trace)
  - Trace roughness
  - Trace width and thickness
  - Trace Length

- *Signal integrity is often the most important need in a design.*
- *As speed increases, loss becomes more important.*

Total loss = Dielectric loss + Conductor Loss

Rolled Annealed Copper performs well at high speeds

ROYAL FLEX CIRCUITS

Design for fab, Design for success!

Flex Building Blocks

Royal Flex Circuits EngineeringTeam will make recommendations for the best stack-up based on the design.

For example: Stripline flex in the bend area will need “no-flow” prepreg in the rigid transition layer.

Overview: Film Types

Type	Properties	Applications
Pyralux AP, AG and AC	Copper clad Polyimide Film	Basic clad building block for circuits
LF and FR Adhesive	Acrylic Thermoset	Coverlay, bondply Multilayer
Pyralux GPL Adhesive (New)	Thermoset Epoxy Blend	Coverlay, bondply multilayer
Pyralux HT	Thermoplastic Polyimide	Coverlay, bondply High Temp, High Speed
Pyralux TK	Teflon/Kapton composite	Coverlay, bondply and clad Very High Speed

Pyralux AG

All Polyimide Flex Materials

Key Benefits

- Superior flexibility
- Diverse offerings for thin applications
- Available in rolls & sheets
  - Enables large format constructions
- Adhesiveless construction
  - Meets IPC4204/11
- Drop in PCB process friendly

Property	Pyralux® AG182518RY	Pyralux® AP8515R
MIT Flex Testing With LF0110 Coverlay 6 mil L/S R=0.38	2100 cycles	1800 Cycles

*single sided with LF0110 coverlay to simulate real world performance.

Laminates Property	IPC-TM-650 (*or other)	Typical Data		
		AG181218RY	AG182518RY	AG185018RY
Adhesion to Cu (Peel Strength) As fabricated, N/mm (lb/in) After solder, N/mm (lb/in)	Method 2.4.9	 > 1.0 (6) > 1.0 (6)	 > 1.0 (6) > 1.0 (6)	 > 1.0 (6) > 1.0 (6)
Dimensional Stability (MD/TD) After etching, % After 150°C/30min. aging, %	Method 2.2.4	 +/- 0.07% +/- 0.07%	 +/- 0.07% +/- 0.07%	 +/- 0.07% +/- 0.07%
MIT Bending, cycles R=0.8mm	JIS C6471	>3500	>1500	>300
Solder Float at 288°C/10sec.	Method 2.4.13 With pre-bake	No blister No delamination	No blister No delamination	No blister No delamination

Pyralux AG

Product	Description	AP equivalent	Available Date
AG121212EM	1/3 oz ED Cu 0.5 mil Kapton	AP7411E	Now
AG121212RY	1/3 oz RA Cu 0.5 mil Kapton	AP7434R	Now
AG181218RY	1/2 oz RA Cu 0.5 mil Kapton	AP7413R	Now
AG122512RY	1/3 RA Cu 1 mil Kapton	AP7164R	Now
AG182518EM	1/2 oz ED Cu 1 mil Kapton	AP8515E	Now
AG182518RY	1/2 oz RA Cu 1 mil Kapton	AP8525R	Now
AG185018EM	1/2 oz ED Cu 2 mil Kapton	AP8525E	Now
AG185018RY	1/2 oz RA Cu 2 mil Kapton	AP8525R	Now
AG092509EN	1/4 oz ED Cu 1 mil Kapton	AP7163E	Now
AG352535RHV	1 oz RA Cu 1 mil Kapton	AP9111R	Now
AG352535EZ	1 oz ED Cu 1 mil Kapton	AP9111E	Mid May
AG091209EN	1/4 ED Cu 0.5 mil Kapton	AP7409E	Mid May
AG122512EM	1/3 ED Cu 1 mil Kapton	AP7164E	Mid May
AG071207EL	1/5 oz ED Cu 0.5 mil Kapton	AP7457E	June ETA
AG072507EL	1/5 oz ED Cu 1 mil Kapton	AP7390E	June ETA

Pyralux GPL

Modified Epoxy Adhesive

DuPont Pyralux GPL adhesive is specifically formulated for high-speed high-frequency flexible circuit applications. With a DK of 2.8 nd a Df of 0.0035 the material is unmatched in its performance and process friendly capabilities.

Loss characteristics

DK 2.8 @ 10 Ghz
Df 0.0035 @ 10 Ghz

Incredibly Sticky

25 um average is 2 N/mm or 11 Lbs/inch!

Constructions

Product Code	Adhesive Thickness & Variation	Samples
GPL0015	15 µm ± 10%	Available
GPL0025	25 µm ± 10%	Available
GPL0030	30 µm ± 10%	Available

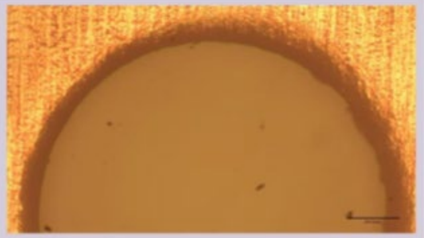
Note: other constructions (20, 35 and 50µm) are available based on customer request.

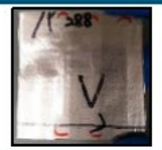
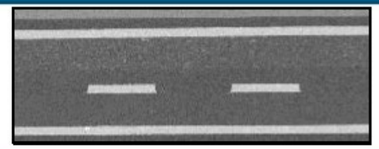
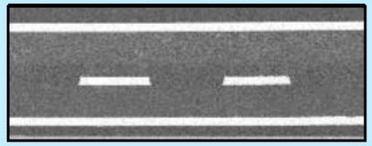
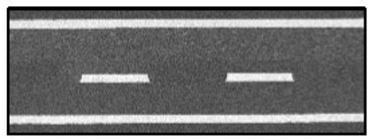
Pyralux GPL

Material Characteristics

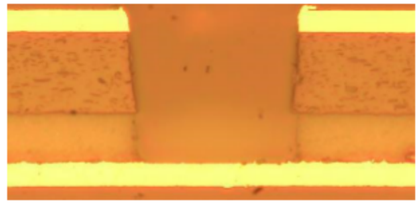
- Hot bar testing shows no delamination with temperatures exceeding 340C
- MV process friendly
- Repeat lamination shows superior resin flow control
- Low laminating temperature @ 190 C or 374 F

Pyralux® GPL



Set Temperature (°C)	Visual Appearance	Cross-Section	Evaluation
288 °C			No Delamination
320 °C			No Delamination
340 °C			No Delamination

After Laser Drill



Etch Back

Average: 4.5 µm

Maximum: 6.0 µm

After Plating

Low/High Power

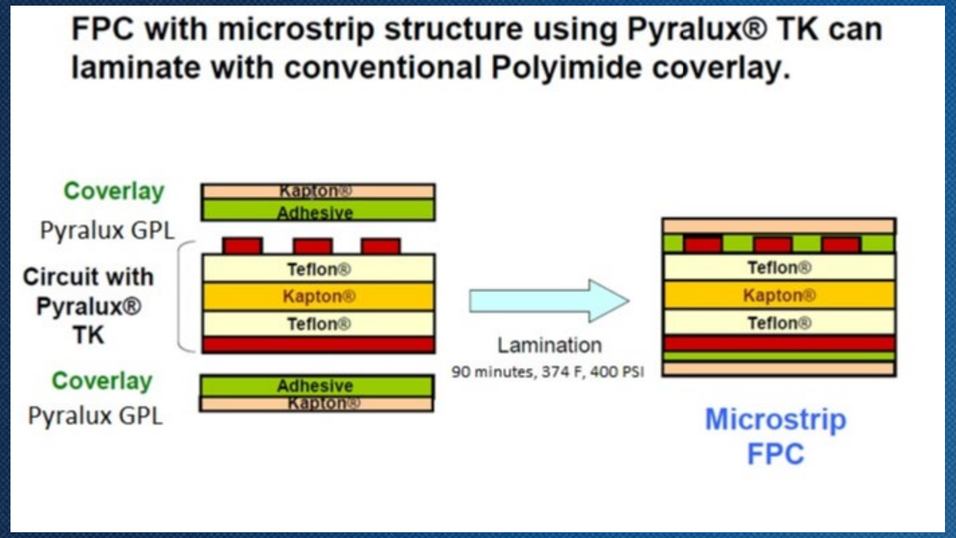
No delamination

Issues at via bottom

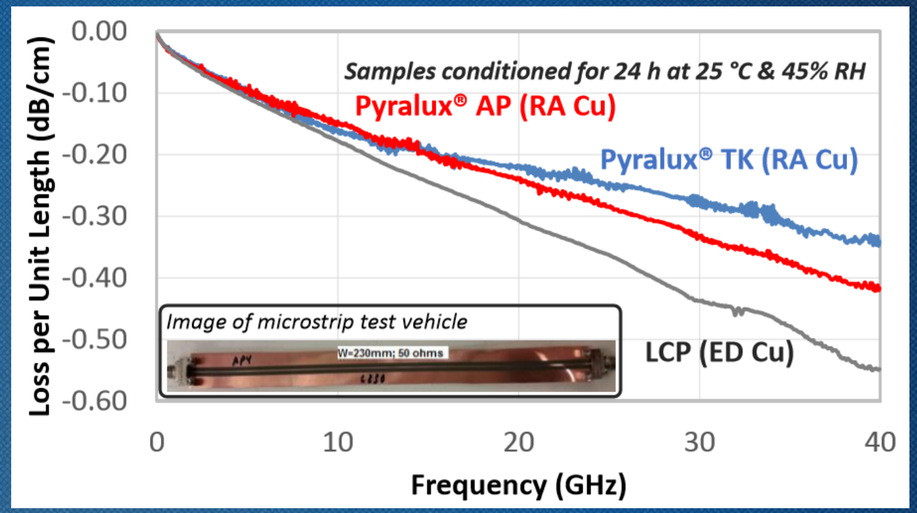
Pyralux TK and GPL

A low loss solution without needing investments

- GPL has great loss characteristics, and does not require high temperature lamination like HT does.
- A combo of TK and GPL would yield a very low loss board without needing special processing requirements.



Products	DK	DF
Pyralux GPL	2.8	0.0035
Pyralux TK	2.5	0.002



* Would need to laminate GPL to Kapton, coverlay option of GPL coming later in 2020.

HT Bonding Film – Used for Bondply or Coverlay

- Homogeneous thermoplastic film.
  - Similar to thermoplastic layer of AP or HT clad
  - No curing or cross-linking involved
  - Very viscous – no flow

- Multi-Functional: Bondply or Coverlay
  - No reinforcing film required due to high viscosity
  - Different thicknesses available (1-4 mil)

- Very good High Frequency Performance
  - No Acrylic!
  - Dk=3.2, Df=0.003
  - Low moisture absorption

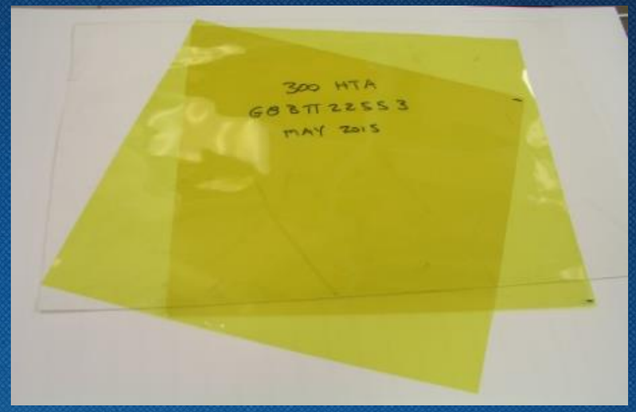
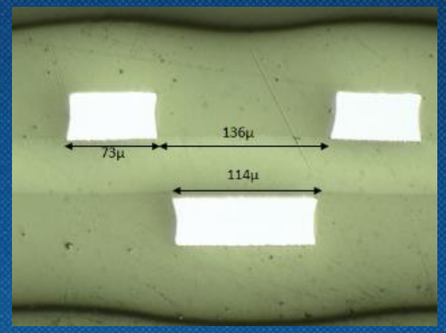


Table 2 - DuPont™ Pyralux® HT Bonding Film

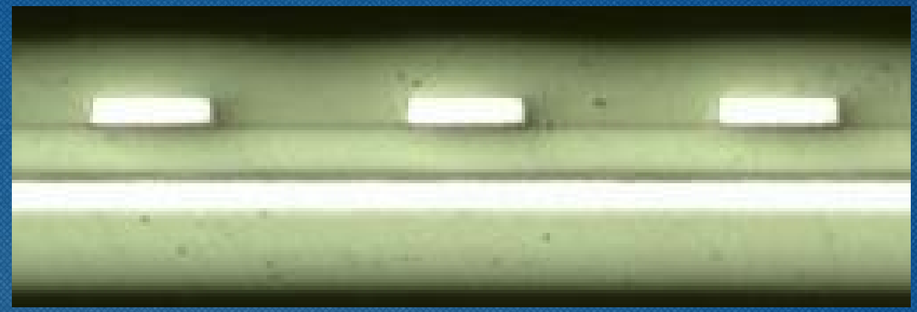
Pyralux® HT Code	Film Thickness, microns	Film Thickness, mils
HT0100	25	1
HT7049	38	1.5
HT0200	50	2
HT0300	75	3
HT0400	100	4

Examples – HT as a Coverlay

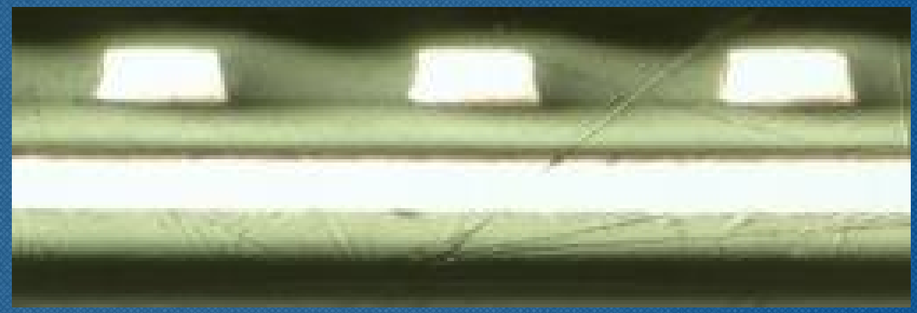
- HT9121R with HT0300
  - DS 1 oz Cu over 2 mil PI
  - 3 mil HT Coverlay



- HT8525R with HT0200
  - DS 0.5 oz Cu over 2 mil PI
  - 2 mil HT Coverlay



- HT9121R with HT0200
  - DS 1 oz Cu over 2 mil PI
  - 2 mil HT Coverlay



General:

Even though flex circuits are very pliable and flexible, there are limits to their flexibility. If the bend radius is too tight, the result can be de-lamination and conductor fracture.

Design Rules:

- For single and double-sided flexible printed wiring boards (PWBs), the minimum bend radius should be six times the overall thickness.

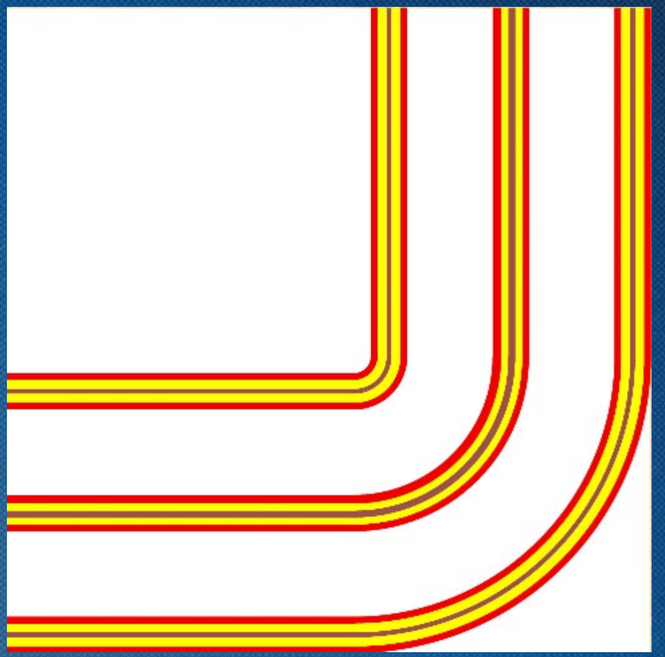
  Example:

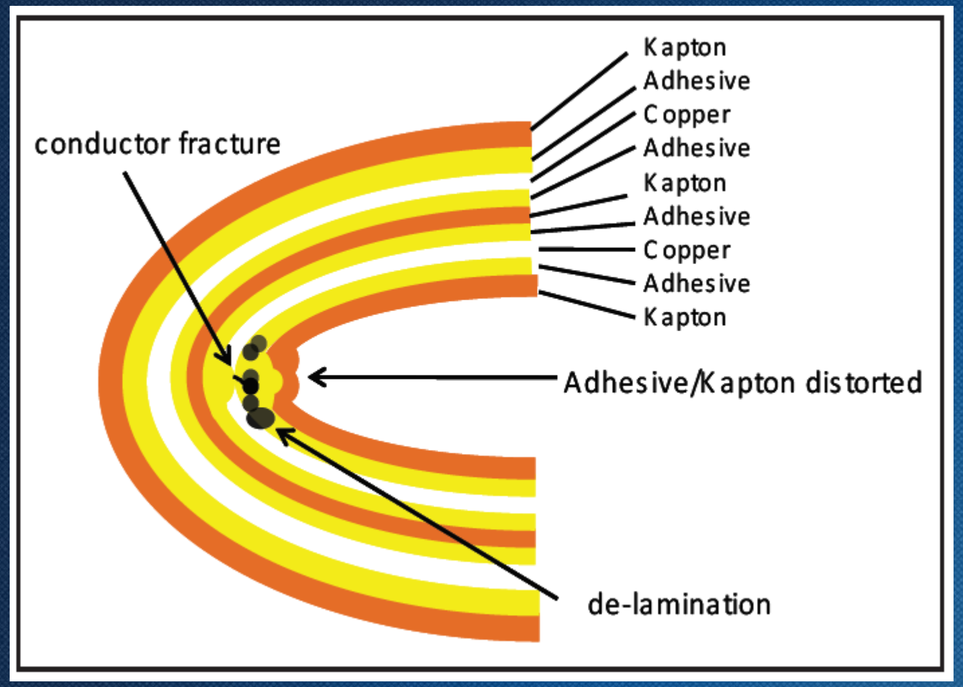
  if the overall thickness of the flex circuit is .012", the minimum bend radius should be .072"

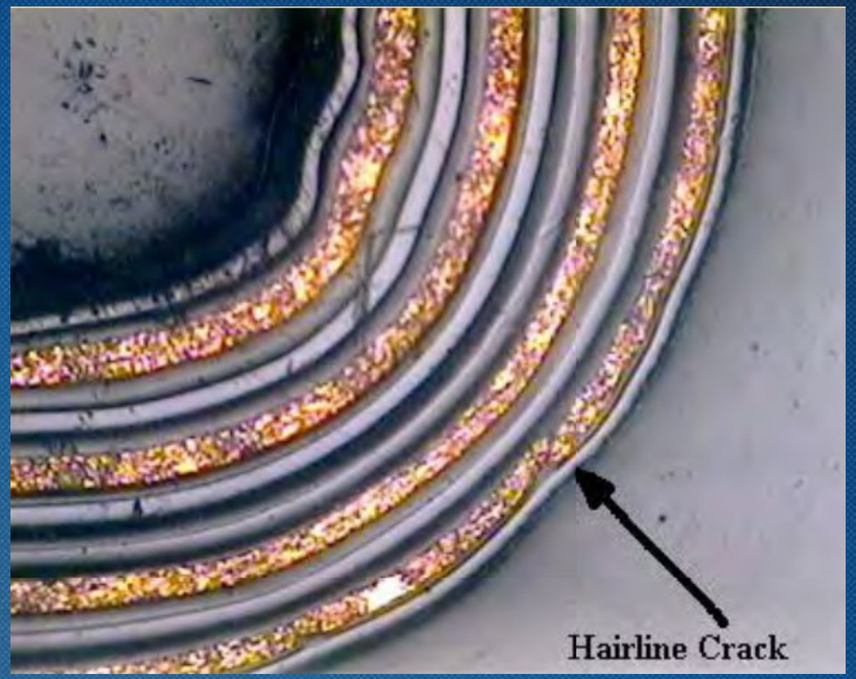
- For multilayer flexible printed wiring board and multilayer rigid and flexible printed wiring board, (bonded inner layers), the minimum bend radius should be 12 times the overall thickness.

  Example:

  if the overall thickness of the flex circuit is .030", the minimum bend radius should be .360"

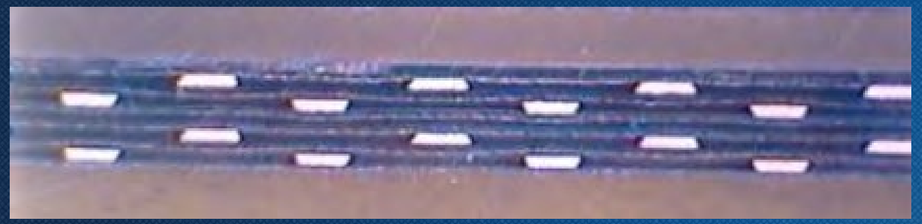



Kapton
Adhesive
Copper
Adhesive
Kapton
Adhesive
Copper
Adhesive
Kapton
conductor fracture
Adhesive/Kapton distorted
de-lamination


Hairline Crack

“I-Beam”

This



Not This

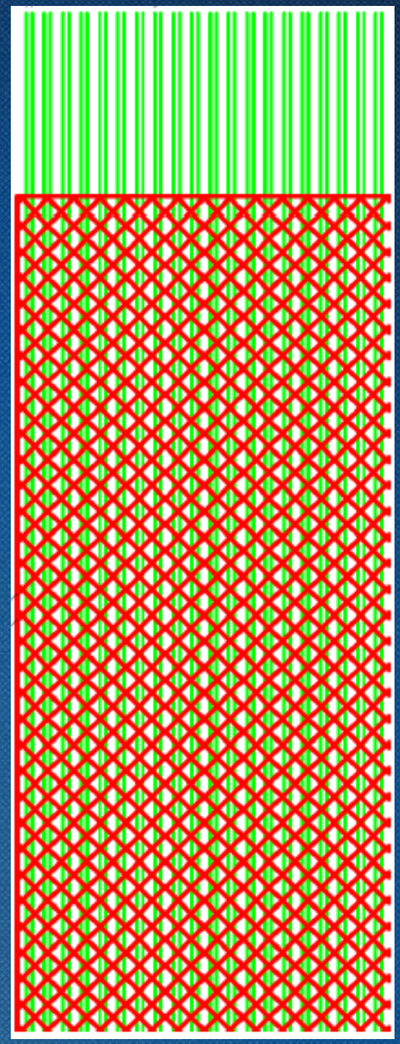
Crosshatched Reference Planes

Good for assembly

Moisture egress

Good for Flexibility

Has signal performance limitations



Reference Plane design (12" x 18")

	1"		17"
	250 mm Long S-Parameter with SMA Launch	100 mm SPP and S-Parameter (SMA)	30 mm SPP (SMA)
11"	250 mm Long S-Parameter with SMA Launch	100 mm SPP and S-Parameter (SMA)	30 mm SPP (SMA)
	250 mm Long S-Parameter with SMA Launch	100 mm SPP and S-Parameter (SMA)	30 mm SPP (SMA)
	250 mm Long S-Parameter with SMA Launch	100 mm SPP and S-Parameter (SMA)	30 mm SPP (SMA)
	250 mm Long S-Parameter with SMA Launch	100 mm SPP and S-Parameter (SMA)	30 mm SPP (SMA)
	250 mm Long S-Parameter with SMA Launch	100 mm SPP and S-Parameter (SMA)	30 mm SPP (SMA)
	250 mm Long S-Parameter with SMA Launch	100 mm SPP and S-Parameter (SMA)	30 mm SPP (SMA)
	250 mm Long S-Parameter with SMA Launch	100 mm SPP and S-Parameter (SMA)	30 mm SPP (SMA)
	250 mm Long S-Parameter with SMA Launch	100 mm SPP and S-Parameter (SMA)	30 mm SPP (SMA)
	250 mm Long S-Parameter with SMA Launch	100 mm SPP and S-Parameter (SMA)	30 mm SPP (SMA)
	250 mm Long S-Parameter with SMA Launch	100 mm SPP and S-Parameter (SMA)	30 mm SPP (SMA)
	250 mm Long S-Parameter with SMA Launch	100 mm SPP and S-Parameter (SMA)	30 mm SPP (SMA)
	250 mm Long S-Parameter with SMA Launch	100 mm SPP and S-Parameter (SMA)	30 mm SPP (SMA)
	250 mm Long S-Parameter with SMA Launch	100 mm SPP and S-Parameter (SMA)	30 mm SPP (SMA)
	250 mm Long S-Parameter with SMA Launch	100 mm SPP and S-Parameter (SMA)	30 mm SPP (SMA)
	250 mm Long S-Parameter with SMA Launch	100 mm SPP and S-Parameter (SMA)	30 mm SPP (SMA)
	250 mm Long S-Parameter with SMA Launch	100 mm SPP and S-Parameter (SMA)	30 mm SPP (SMA)
	250 mm Long S-Parameter with SMA Launch	100 mm SPP and S-Parameter (SMA)	30 mm SPP (SMA)
	250 mm Long S-Parameter with SMA Launch	100 mm SPP and S-Parameter (SMA)	30 mm SPP (SMA)
	250 mm Long S-Parameter with SMA Launch	100 mm SPP and S-Parameter (SMA)	30 mm SPP (SMA)
	250 mm Long S-Parameter with SMA Launch	100 mm SPP and S-Parameter (SMA)	30 mm SPP (SMA)
1"	250 mm Long S-Parameter with SMA Launch	100 mm SPP and S-Parameter (SMA)	30 mm SPP (SMA)

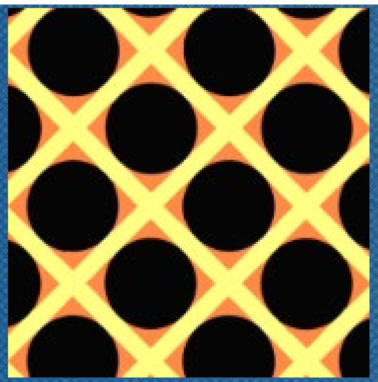
Control: 100% Copper Coverage

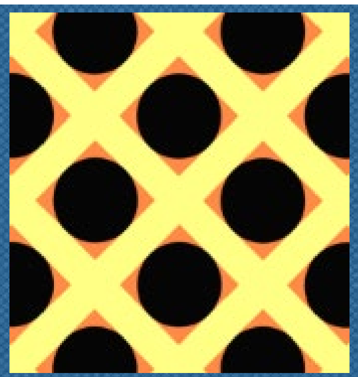
50% Copper Coverage

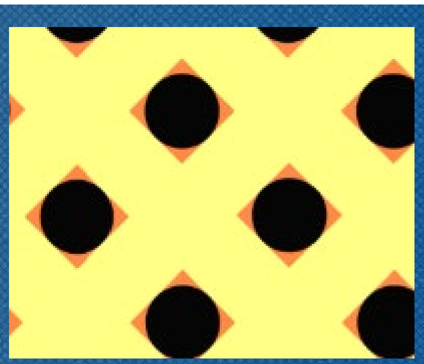
25% Copper Coverage

75% Copper Coverage

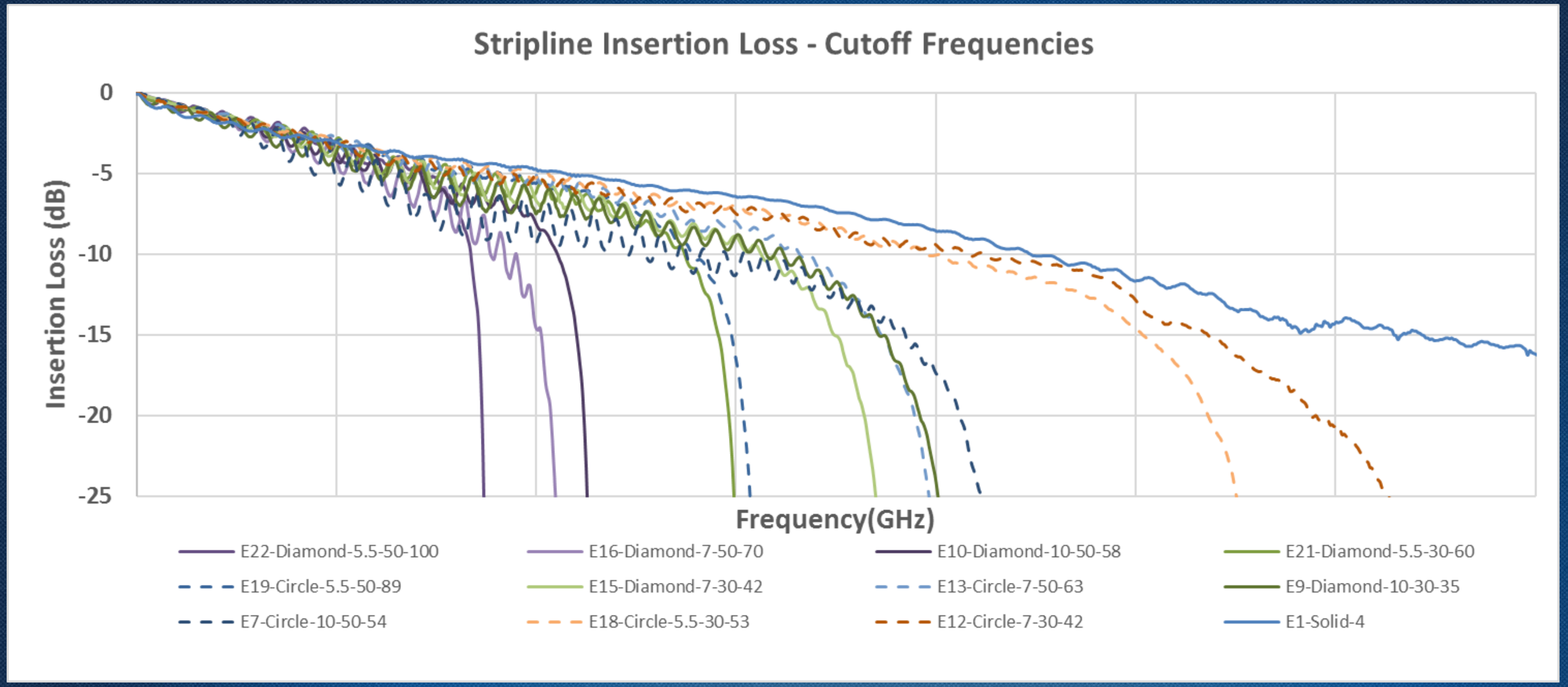
All coupons 0.5" wide.
100 mm coupon used for both SPP and S-Parameter tests.





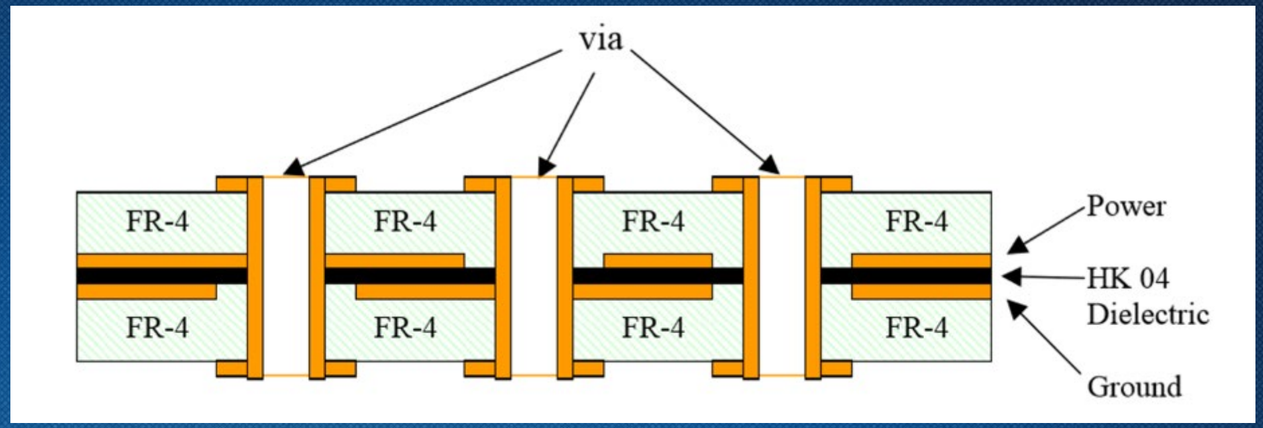


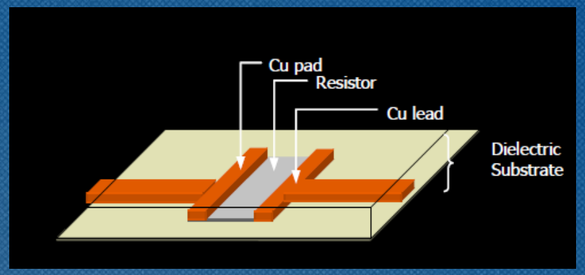
Stripline – Passband/Stopband

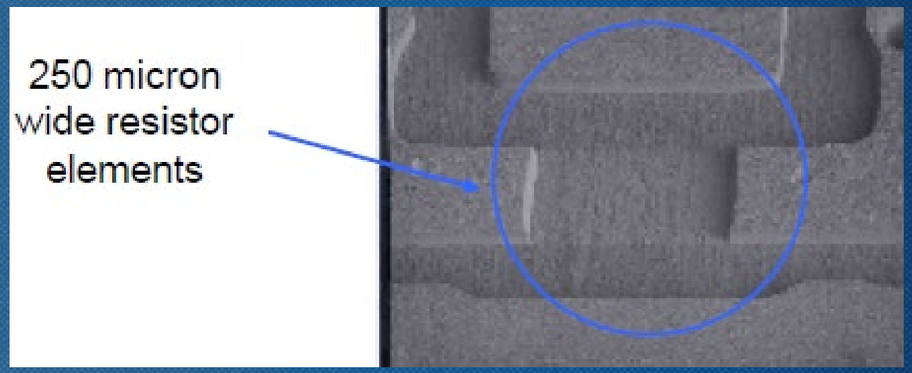


Other Technology

- Embedded Capacitors
  - Flex layer in rigid PCB
- Embedded Resistors
  - Pyralux® APR
- Screenable Components
- Z-Axis Paste interconnets







Questions?

Email Lisa@royalcircuits.com, riki@royalflexcircuits.com or CHunrath@Insulectro.com with additional questions

Thank you!

– Royal Flex Circuits

Chris Hunrath – Insulectro