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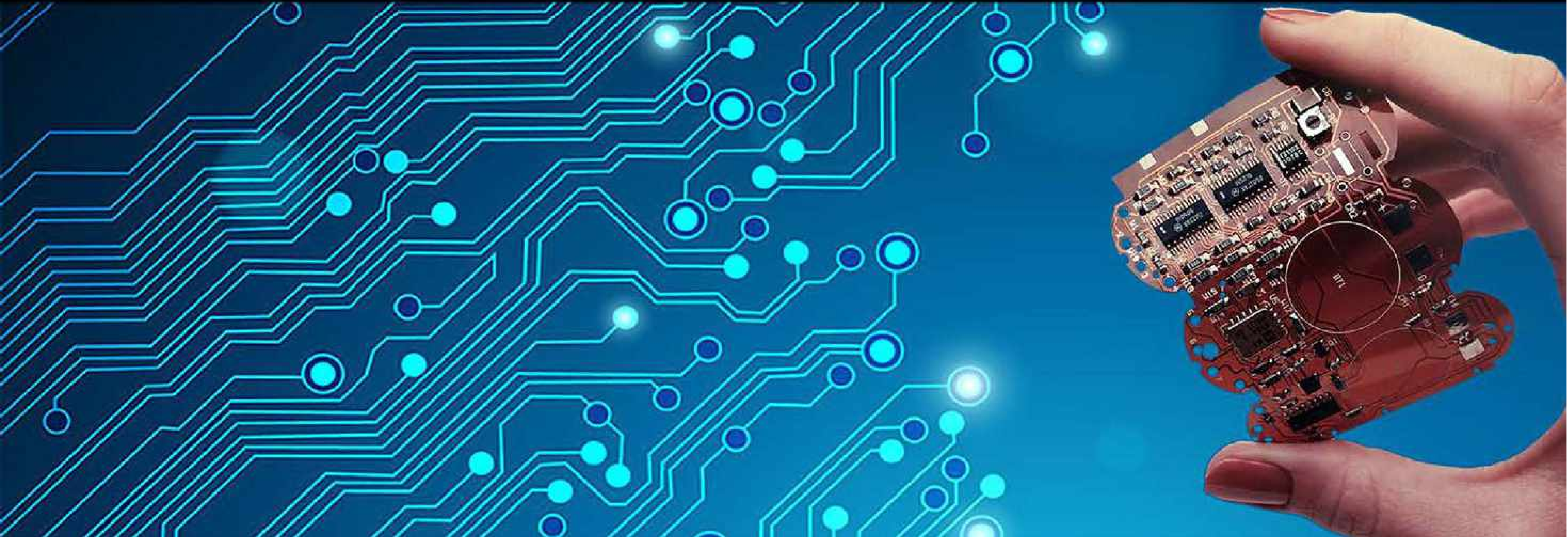
Leading the Way in Advanced Materials Solutions

FLEX CIRCUIT DESIGN GUIDELINES FOR OPTIMIZING PERFORMANCE



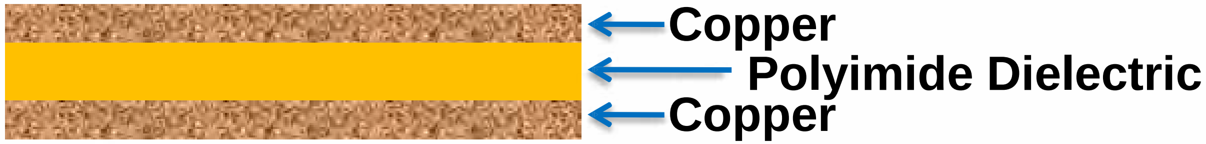
SPECIFICATIONS

IPC FLEX CIRCUIT SPECIFICATIONS

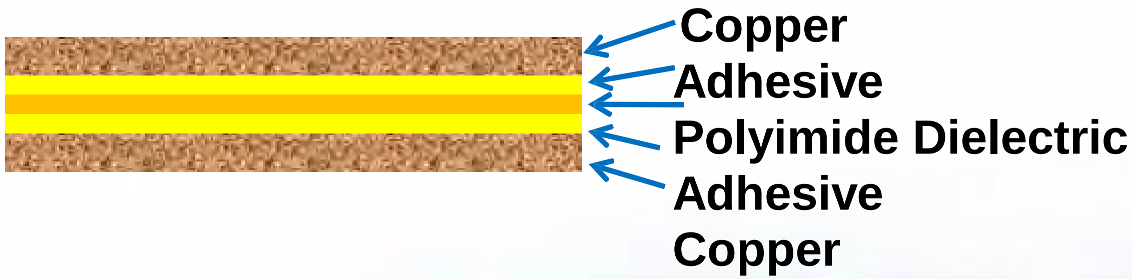
- *IPC 2221 Generic Standard on Printed Board Design*
- *IPC 2223 Sectional Design Standard for Flexible/Rigid-Flexible Printed*
- *IPC 6013 Qualification and Performance Specification for Flexible/Rigid-Flexible Printed Board*
- *IPC 4204 Flexible Metal-Clad Dielectrics for Use in Fabrication of Flexible Printed Circuitry*
- *IPC 4203 Adhesive Coated Dielectric Films for Use as Cover Sheets for Flexible Printed Circuitry and Flexible Adhesive Bonding Films*
- *IPC 4202 Flexible Base Dielectrics for Use in Flexible Printed Circuitry Metal Foil for Printed Board Application*
- *IPC 4562 Metal Foil for Printed Board Application*
- *IPC 4101 Specification for Base Materials for Rigid and Multilayer Printed Board*

MATERIALS

FLEXIBLE METAL CLAD DIELECTRIC



IPC 4204/11 E1E2 CU W7 1S/1S



IPC 4204/1 E1E1 M1/1 CU W7 1S/1S

- *Adhesive-less generally used for Rigid/Flex or “high performance applications"*
- *Adhesive based generally used for single/double sided or low layer count multilayer flex applications. Use a flame retardant version for those specific applications*

FLEXIBLE ADHESIVE COATED DIELECTRIC

Covercoat

Polyimide Dielectric
Adhesive

IPC 4203

Bond Ply

Adhesive
Polyimide Dielectric
Adhesive

IPC 4203

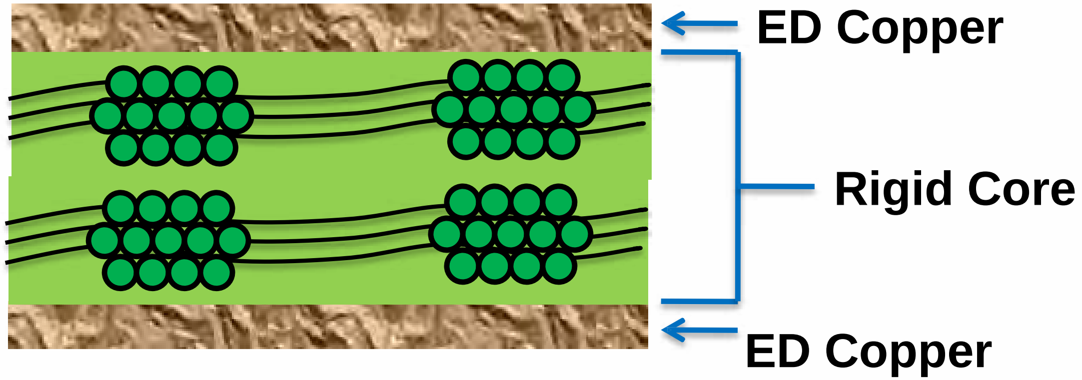
Sheet Adhesive

Adhesive

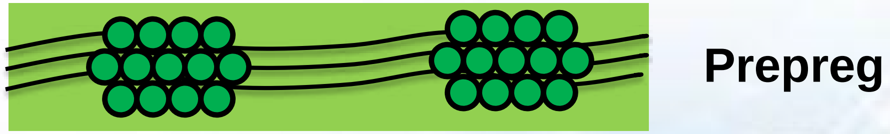
IPC 4203

- **When Flame Retardancy is required (i.e. UL94VTM-0).**

RIGID METAL CLAD DIELECTRIC & PREPREG

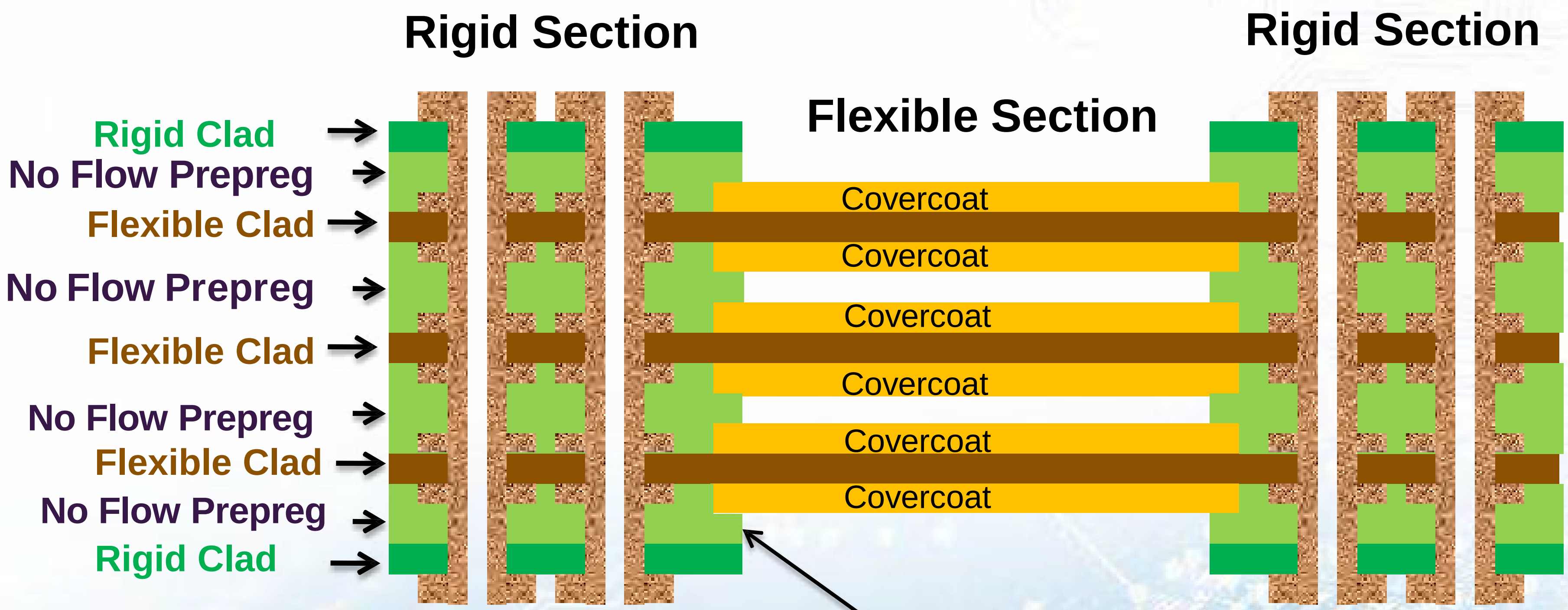


- *Rigid Metal Clad Dielectric IPC 4101 GIL 0050 HH/HH*
- *Used for Rigid Outers & Non-Flexing Inner Layers*



- *No Flow Prepreg IPC 4101/42 GIJ 1080 glass*
- *Used to Bond Flex Layers together with minimal resin flow into flex section*
- *Available only in Polyimide & Epoxy Resins with 1080/106 glass styles*

ADHESIVE-LESS BIKINI CONSTRUCTION

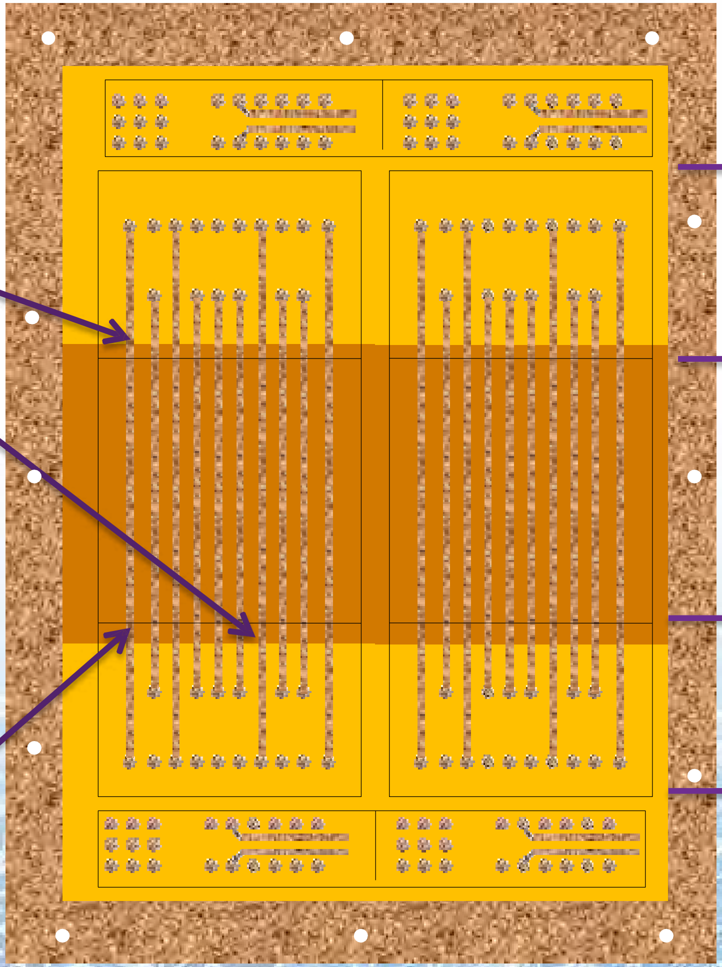


Notice Covercoat does not extend into plated through holes

(Crossection View)

ADDING COVERCOAT "PATCH" TO FLEX INNER LAYER

Note:
Covercoat extends into Rigid Area approx .050"



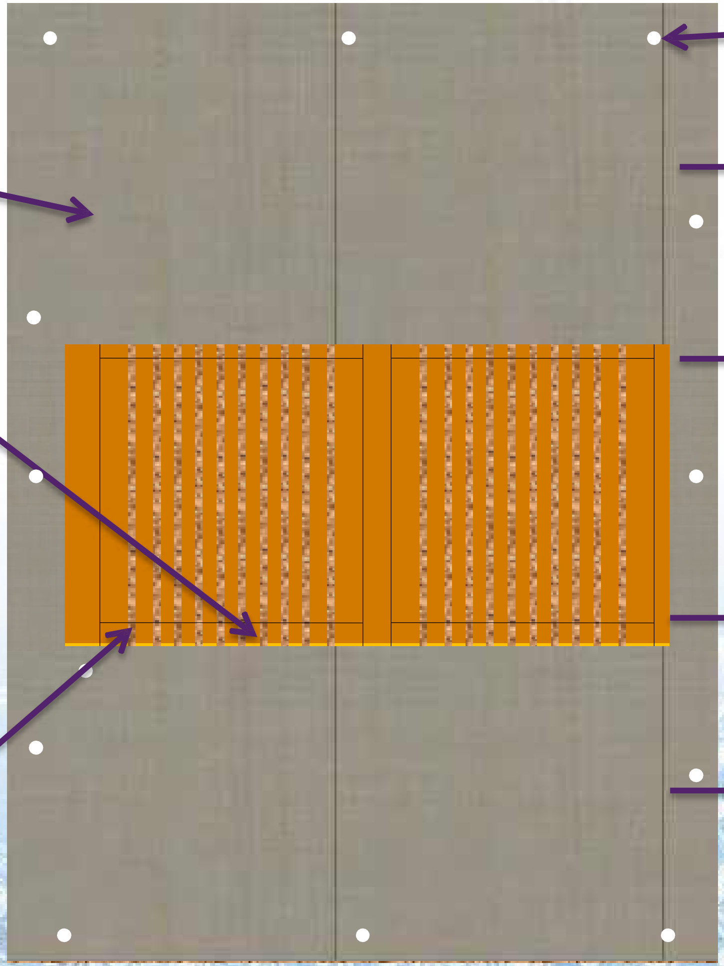
Rigid Area

Flexible Area

Rigid Area

Rigid/Flex Transition

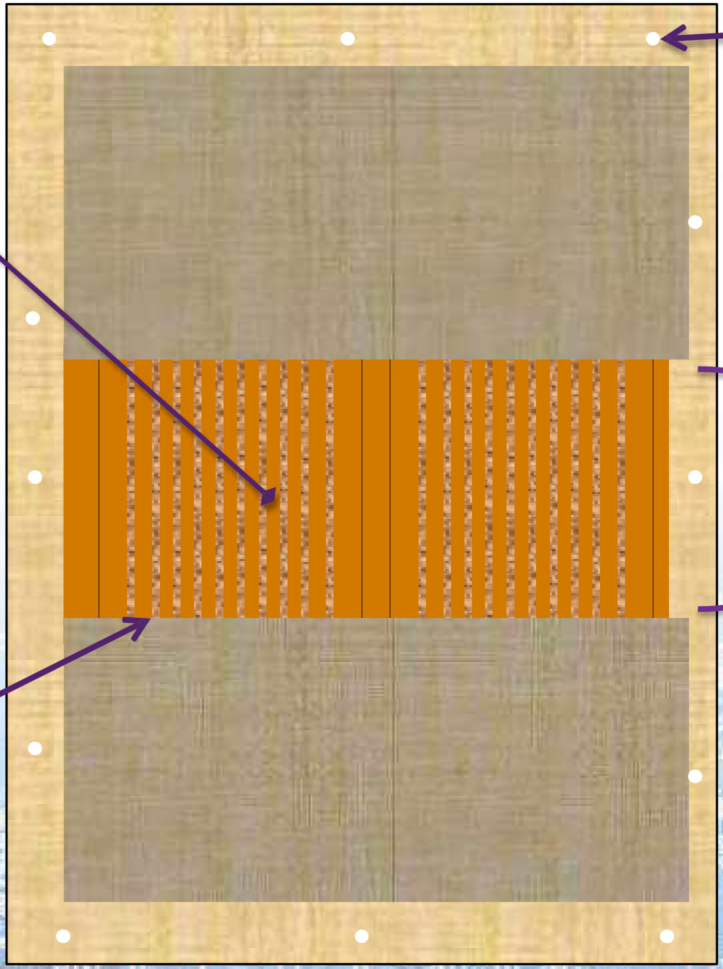
NO FLOW PREPREG PLACED IN NON-COVERCOAT AREA



NO FLOW PREPREG OVERLAPS

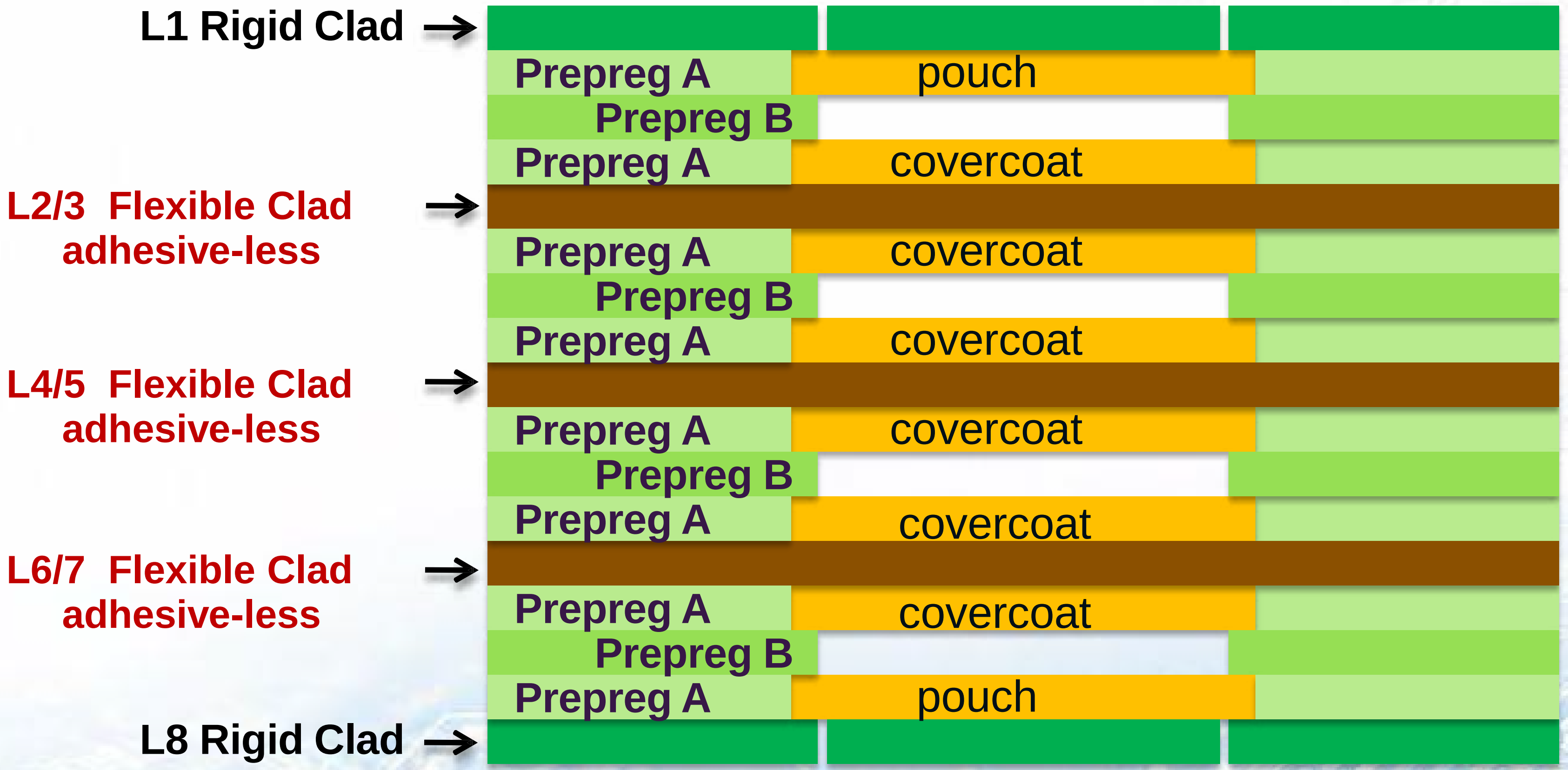
COVERCOATING/PREPREG TRANSITION

Prepreg covers Entire Panel Except Flexible Area



Note: Prepreg extends to Rigid edge

STACKUP OF MATERIALS



Note: Prepreg "A" fills area where covercoat terminates inside rigid section
Prepreg "B" extends to rigid edge

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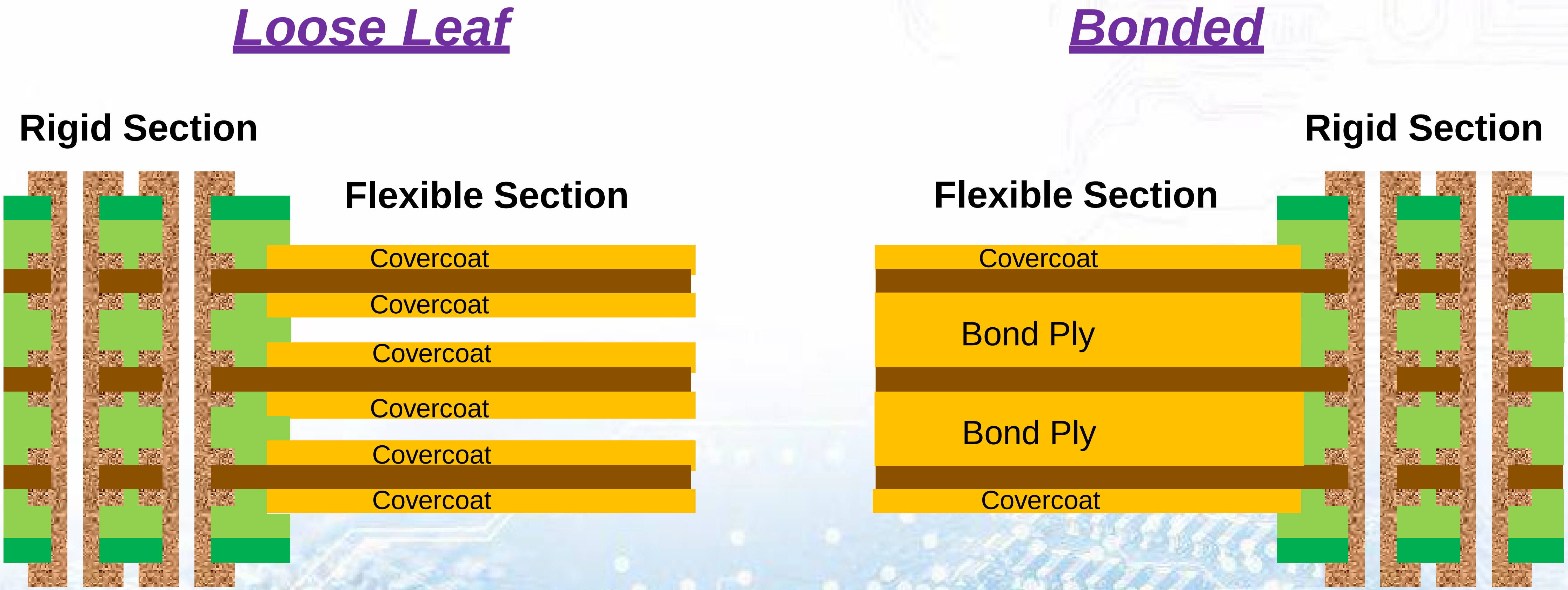
LOOSE LEAF VS. BONDED CONSTRUCTION



LOOSE LEAF VS. BONDED CONSTRUCTION

Loose Leaf

- Most Flexible for 90 & 180° Bends
- Simplest to construct
- Not recommended for Impedance Control (i.e. Stripline)

Bonded

- Less Flexible (stiff) than Loose Leaf. Requires a more generous bend radius
- Requires Sub Lamination with Bond Ply and Pre-preg
- Ideal for Stripline Impedance Control

DESIGN TIPS

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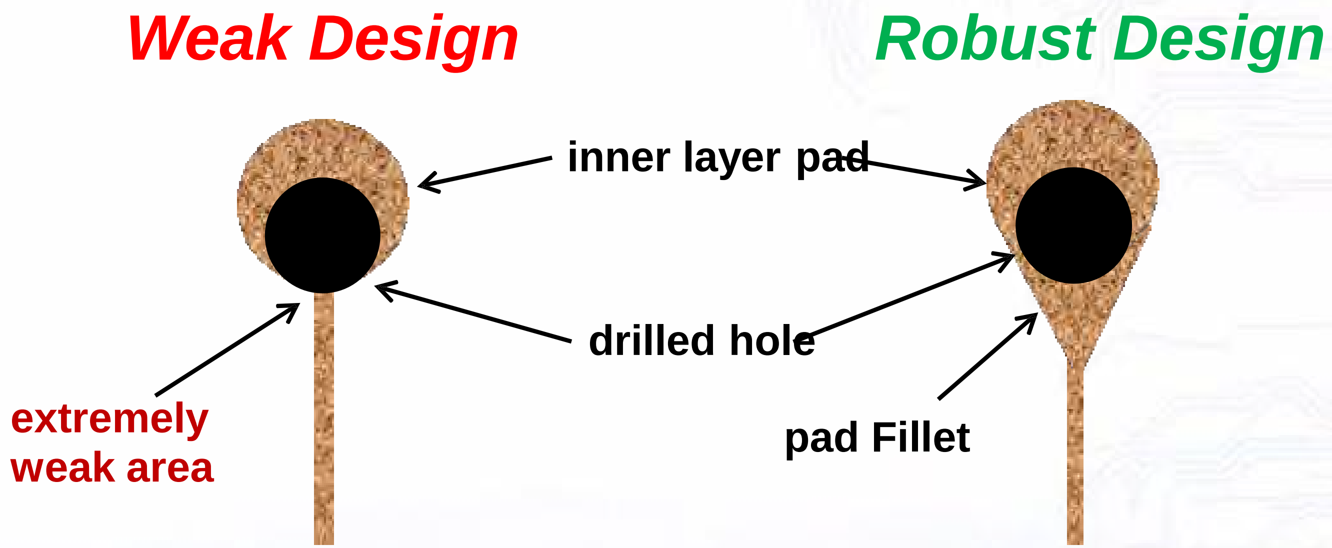
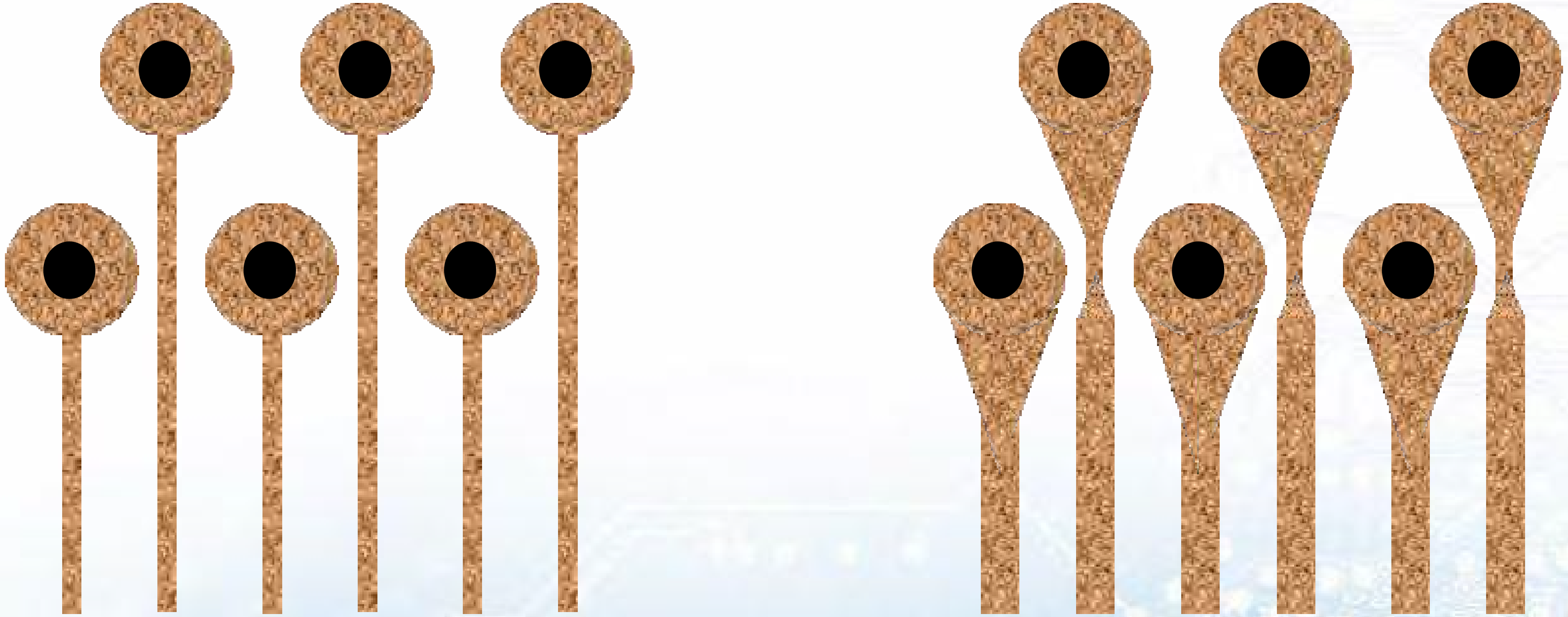
ADDING FILLETS TO PADS/LANDS



- *Mis-registration can leave a poor connection if the hole is shifted towards the conductor.*
- *Adding Fillets to the Lands will increase process latitude and reliability, also adds strength to the interconnect.*

MAXIMIZING CONDUCTOR WIDTHS

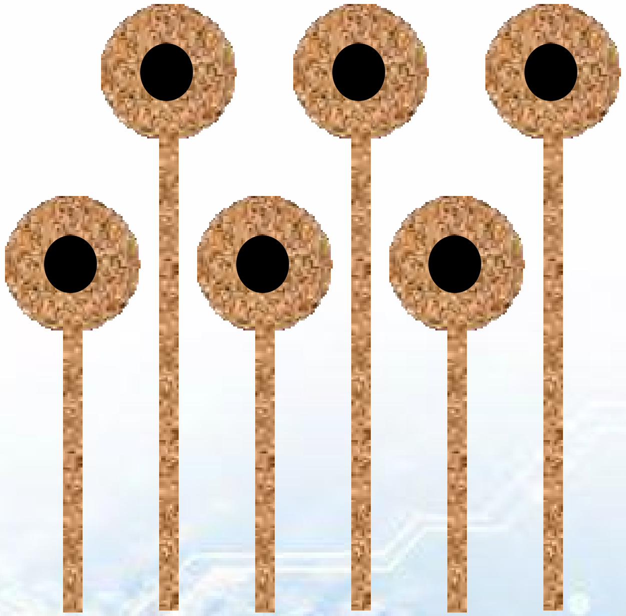
Weak Design *Robust Design*



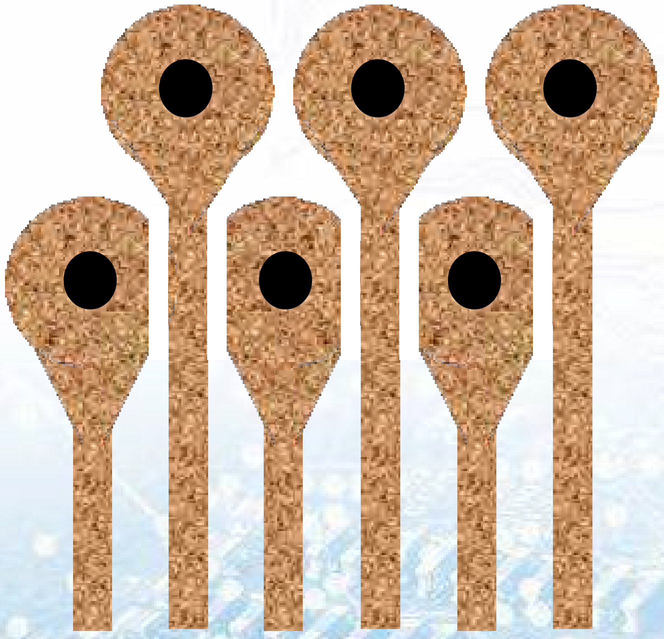
- *Some Designs require narrow conductor width to pass through land areas and ends up being the width for the entire length. Modification as shown above will improve manufacturing yields and reliability.*

MAXIMIZING ANNULAR RING

Weak Design



Robust Design



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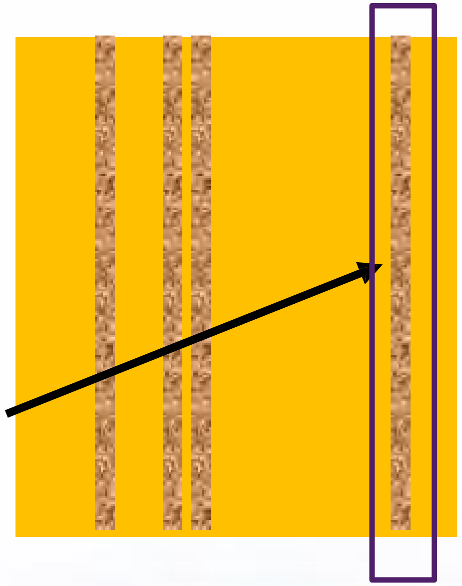
BALANCED CIRCUIT PATTERN (ACROSS FLEX WIDTH)

Weak Design



potential localized stress area

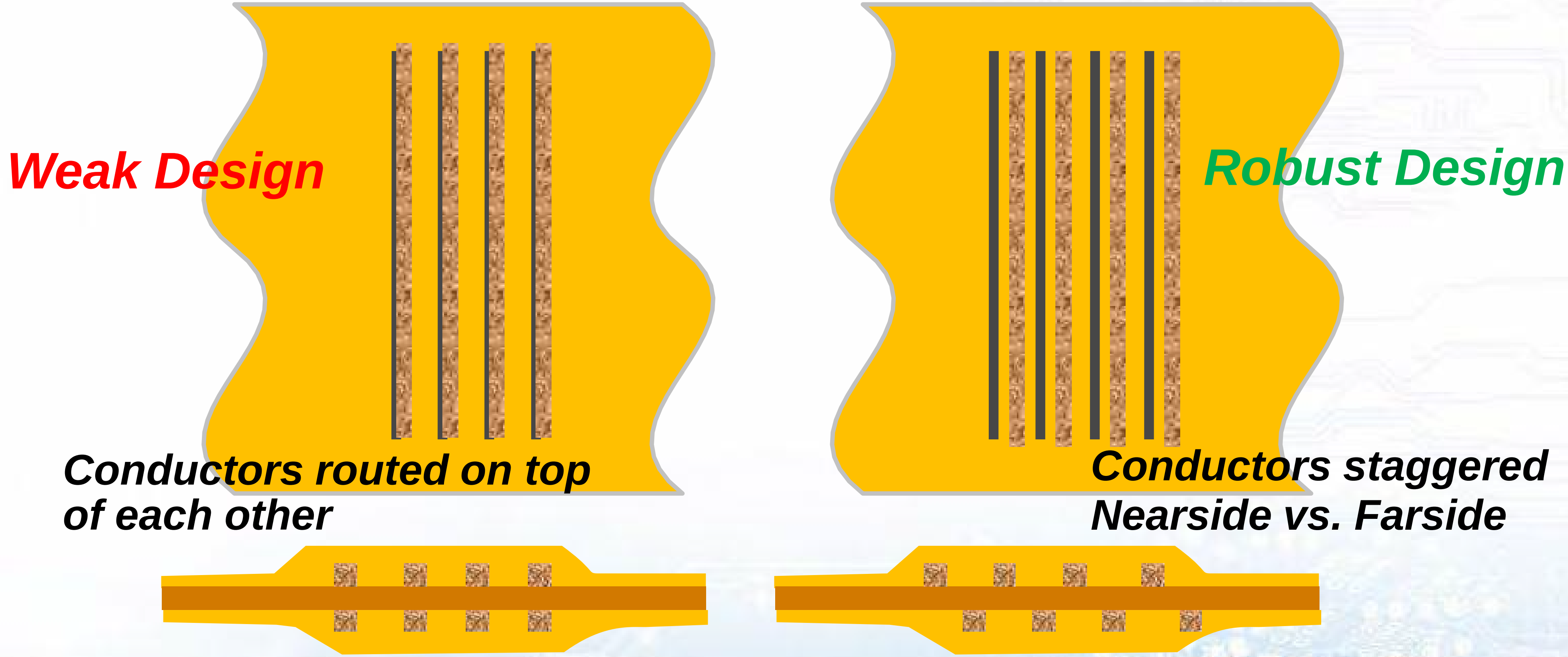
Robust Design

Conductors routed randomly

Conductors evenly balanced

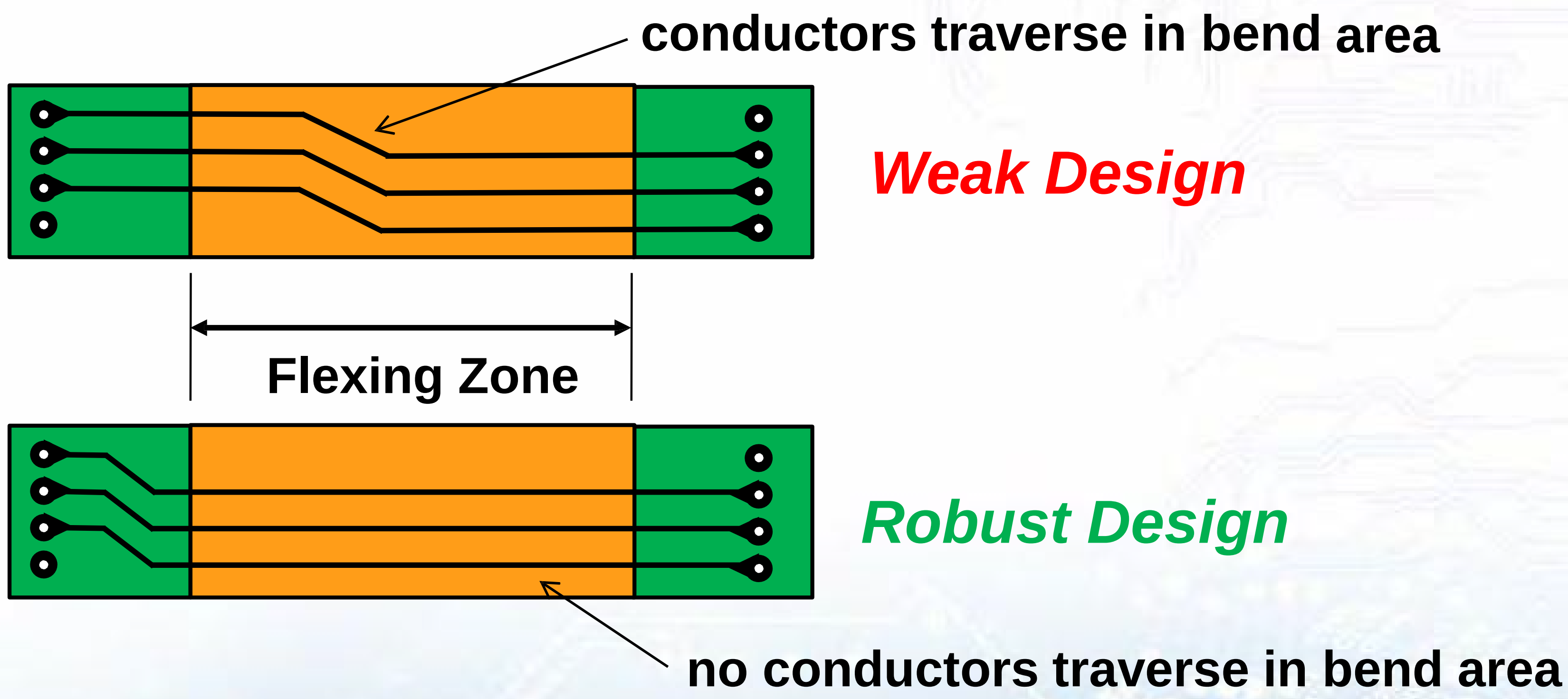
- ***When the flex is bent, the stress will be localized as shown in the Weak Design….reducing flex life***
- ***With the Robust Design, the stress will be evenly distributed across the flex width and not localized….maximizing flex life***

CONDUCTOR “I-BEAMING”



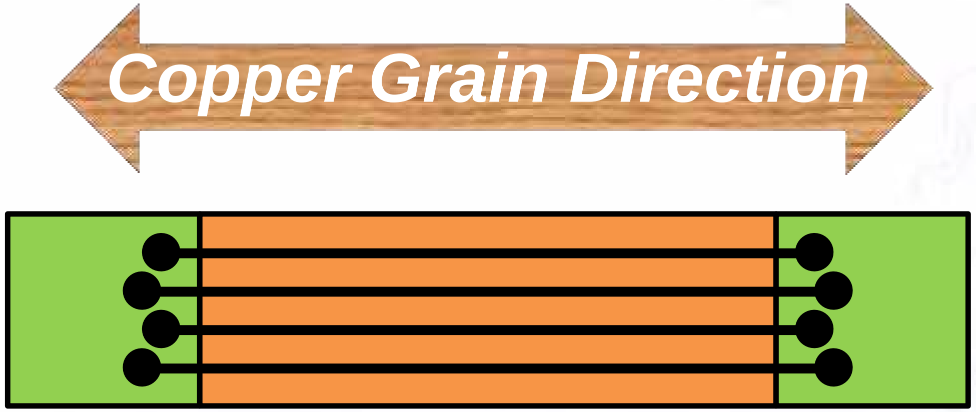
- *With the Weak Design, Bending/Flexing forces the copper to be bent inwards against the opposing conductor causing a premature fracture*
- *With the Robust Design, there is a place for the conductors to “nest”. Eliminates stress on the conductors due to an “I-Beam” condition….maximizing flex life.*

CONDUCTOR ROUTING IN THE FLEXING ZONE



- *With the Weak Design, the conductor angles are potential stress points*
- *With the Robust Design, the traversing conductor routing is done in the “non flexing zone” eliminating any stress points*

COPPER GRAIN DIRECTION AND BEND DIRECTION



- *If RA Copper, Grain Direction should run parallel with the conductors*
- *Bend should be perpendicular to the conductors*

DYNAMIC FLEXING APPLICATION RECOMMENDATIONS

- *Any imperfections in artwork, materials, etch anomalies (i.e. nicks, edge roughness, etc.) can cause a premature failure*
- *The construction should be balanced from its centerline. Unbalancing of materials (includes copper ,dielectric and adhesive thicknesses) will cause stress to occur in one direction decreasing flexure life.*
- *Copper Thickness can impact flex life depending upon the type of flexure*
- *Typically the copper <u>should</u> be type RA (rolled annealed) due to its greater ductility and elongation*
- *Copper Grain Direction should be parallel with conductors*
- *Bend or flexing action should be perpendicular to conductors*
- *Alternate Oxide (copper etch rate removal) should be minimized*
- *The Dielectric Substrate material should be "adhesive-less". Substrate materials with adhesive will fatigue sooner*

DYNAMIC FLEXING APPLICATION RECOMMENDATIONS

- *Thinner overall thickness will outlast thicker constructions*
- *All conductors should be perpendicular to bend area, If this cannot be achieved, the conductors shall have radiused corners*
- *Steel Rule Dies shall not have any blade joints in the flexing area*
- *There shall be no plated through holes in the flexing area*
- *There should be no electrolytic copper on the conductors in the flexing area. "Pad Only" plating process shall be utilized or construct as a Type 3 or 4 where the plating can be confined to the "non flexing" areas*
- *Inner Layers shall not be bonded together in the flexing area (typically referred "loose leaf" construction)*

Note: All the above will benefit "flex to install" applications as well

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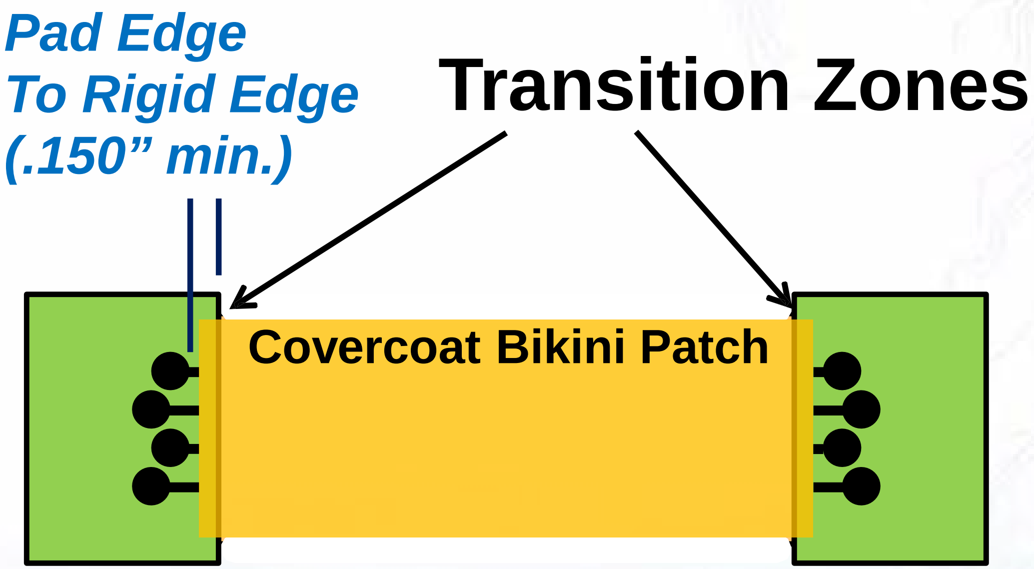
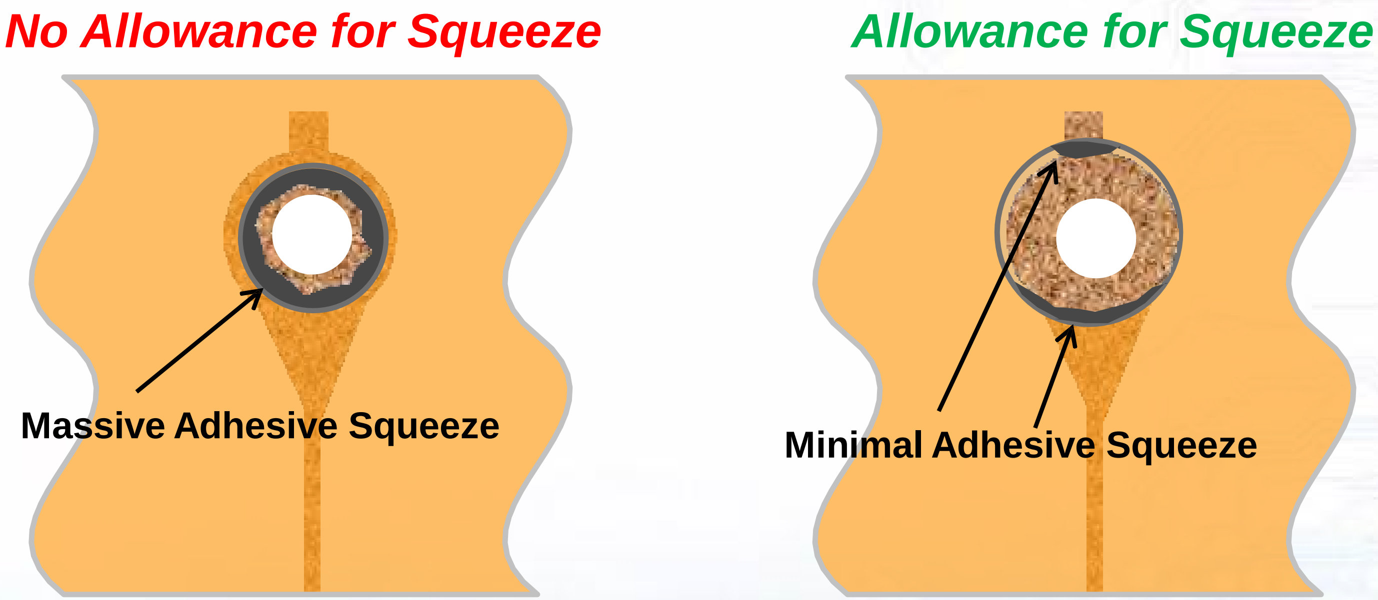
PLATED THROUGH HOLES NEAR TRANSITION ZONE



- *The Transition Zone is where the Covercoat "transitions" to Prepreg*
- ***DO NOT*** *locate Plated Through Holes and their Lands in the Transition Zone….otherwise PTH failures (barrel cracks) can result*

COVERCOAT ADHESIVE SQUEEZE OUT



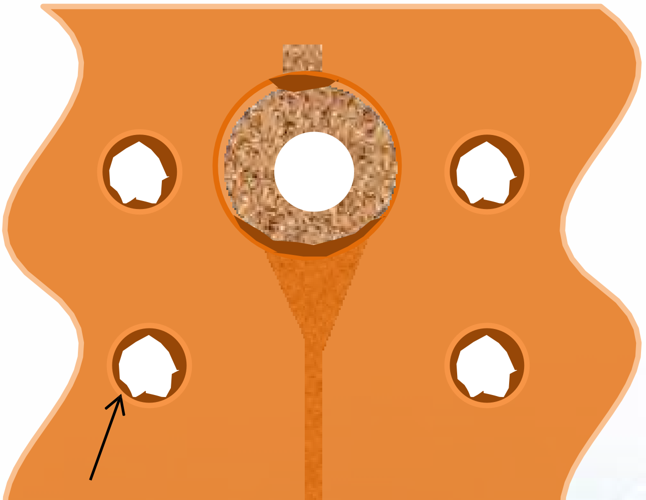
- **A minimum solderable "annular ring" generally required (i.e. .005" or .002"). Depends on:**
  - **Pad Size & Hole Size**
  - **Covercoat Drill Diameter**
  - **Alignment accuracy of the Covercoat to the Etched Features**
  - **Amount of Covercoat Adhesive Squeeze Out from Lamination**

GUIDELINES FOR MAXIMIZING SOLDERABLE ANNULAR RING

- *The Covercoat Drill Diameter should be .005-.010" larger than the pad. Pad will act as a dam to block adhesive from flowing onto Pad*
- *Generally Covercoat Access Holes should not be specified by the designer*
- *Tooling fixtures can help with Alignment of Covercoat*
- *Scaling of Covercoat to <u>match</u> Etched Substrate size*
- *Minimize Covercoat Adhesive Thickness*
- *Optimization of Lamination Processes and Techniques*
- *Laser Ablation <u>after</u> lamination can produce tighter processing tolerances*

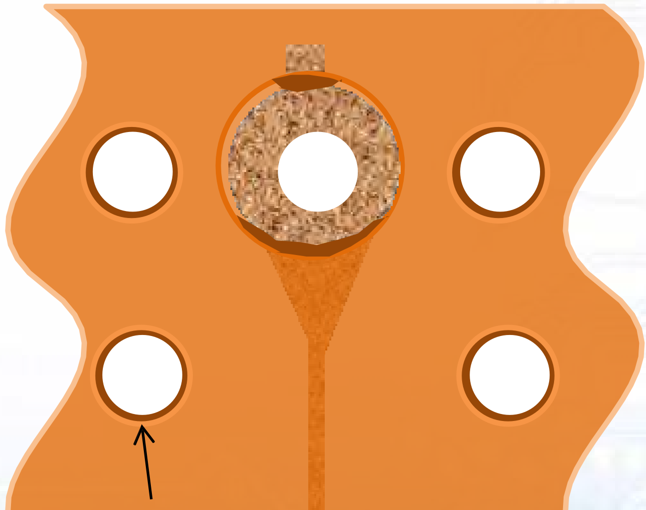
COVERCOAT ADHESIVE SQUEEZE OUT (NON-PLATED THRU HOLES)

Covercoat Clearance Holes Drilled same Diameter as Base Substrate



adhesive squeeze reducing design hole diameter

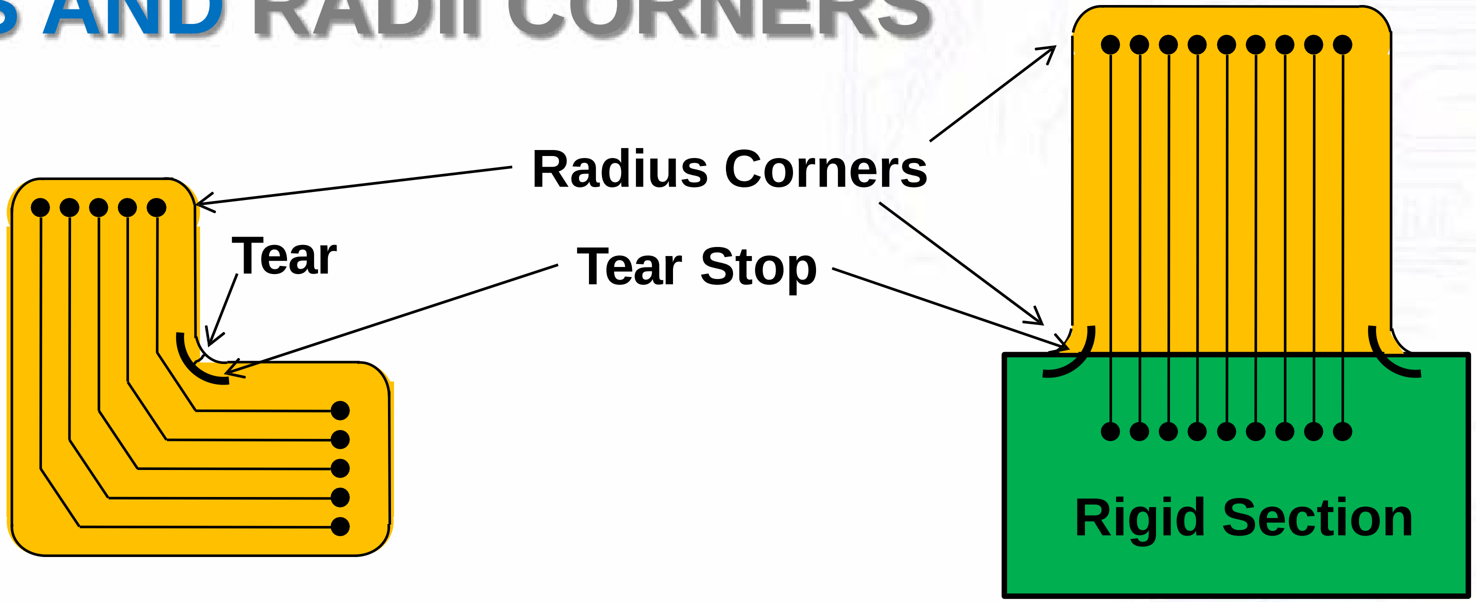
Covercoat Clearance Holes Drilled LARGER than Base Substrate Diameter



adhesive squeeze doesn’t reduce design finished hole diameter

- ***Covercoat Holes must be Drilled <u>larger</u> than finished hole size to account for adhesive squeeze out and mis-alignment***

TEAR STOPS AND RADII CORNERS



Type 1, 2 and Inner Layers

Type 3 and 4

Tear Stops:

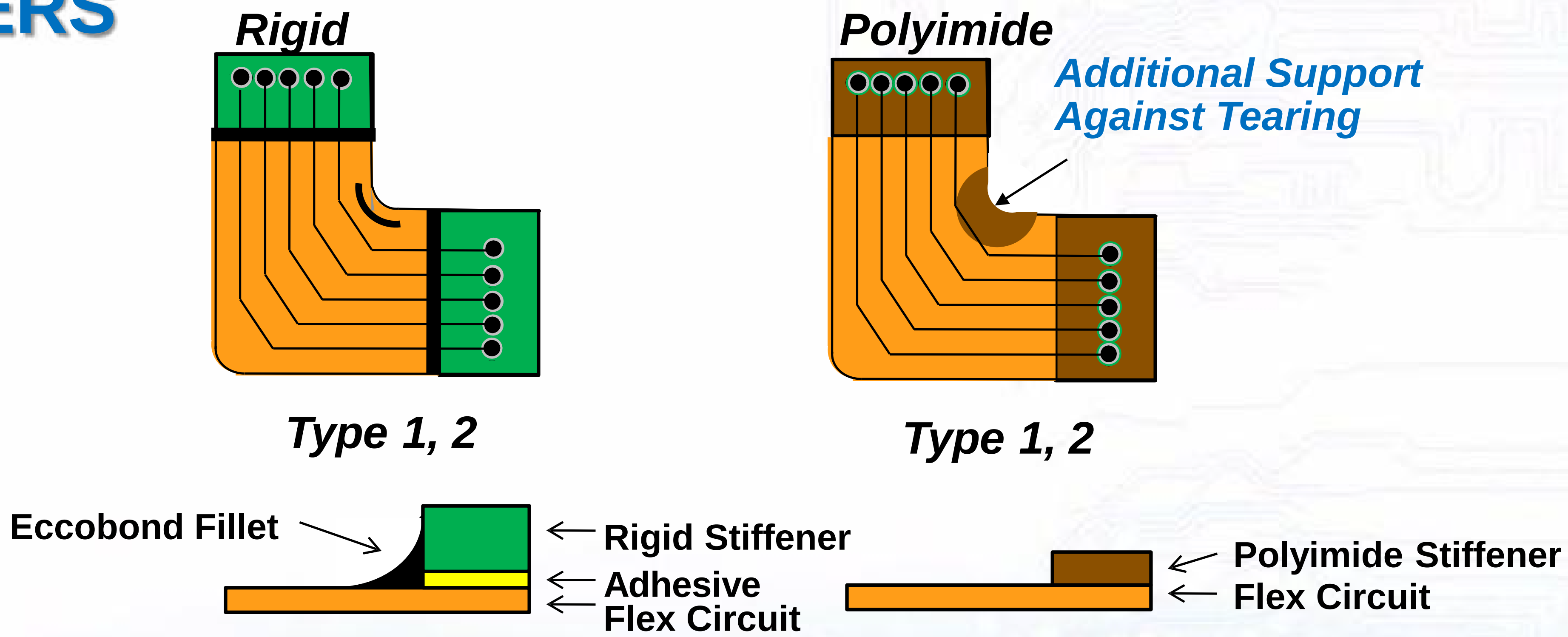
1) To prevent a tear from reaching the critical conductors

2) They are added to the artwork (basically a conductor with no termination). Should be as wide as design permits (.010 - .040”).

Radius Corners to Eliminate Sharp Edges:

1) All inside corners of flexible circuitry shall have radius corners (typically .030-.060” or greater). Most outside corners can be specified as “break the corner” (preferred) or use the same dimensions as the inside corner.

STIFFENERS



General:

Type 1 and 2 flex circuits are generally too thin to adequately support mounting of connectors. Stiffeners are added to the connector mounting area to add mechanical support. There are two types used (Rigid and Polyimide). Both require adhesive for "bonding" and must allow for adhesive squeeze out in access holes.

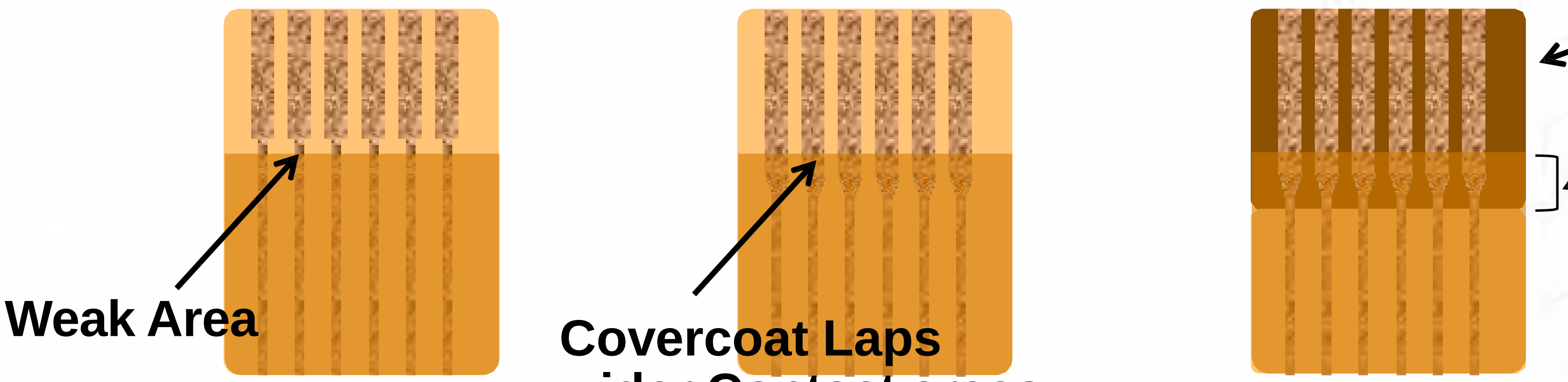
Rigid Stiffeners

- Provide greatest support utilizing a fiberglass substrate w/o copper
- Thickness availability from .010 - .062” (most common .031”)
- Adhesive
- Holes are drilled (typically larger than pad size) to permit access to pad/land areas
- After application, an epoxy fillet is recommended at the rigid/flex transition

Polyimide Stiffeners

- Should only be used when slight stiffness is required
- Advantage = can be applied via Covercoat lamination process (lower cost & time savings)
- Typically material is .002” adhesive with .005” Polyimide
- Holes are drilled (typically larger than pad size) to permit access to pad/land areas
- No epoxy fillet is required

EDGE CONTACTS

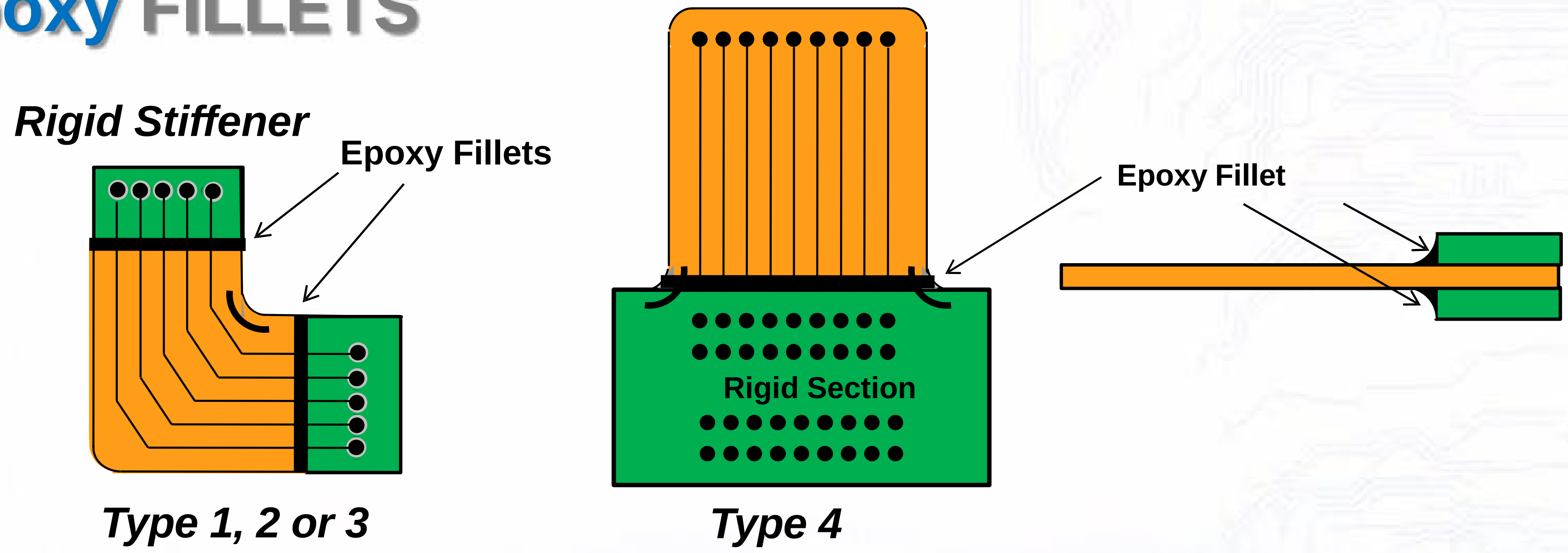


General:

In the Weak Design, the conductors can easily break where the covercoat stops. By extending the length of the contacts or moving the covercoat opening over the contacts, greatly increases resistance to conductor breakage (Robust Design). Adding a Polyimide stiffener will also strengthen and stiffen this area for easier end use installation

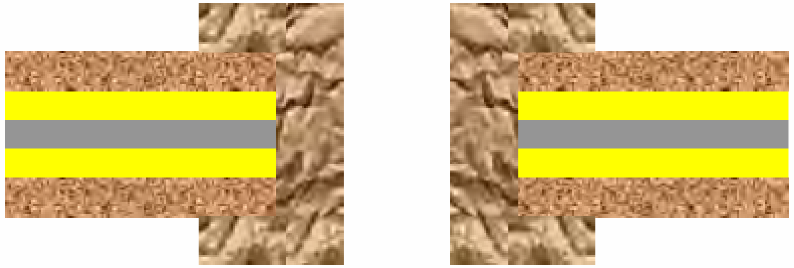
Note: must allow for covercoat adhesive flow onto contact area

Epoxy FILLETS

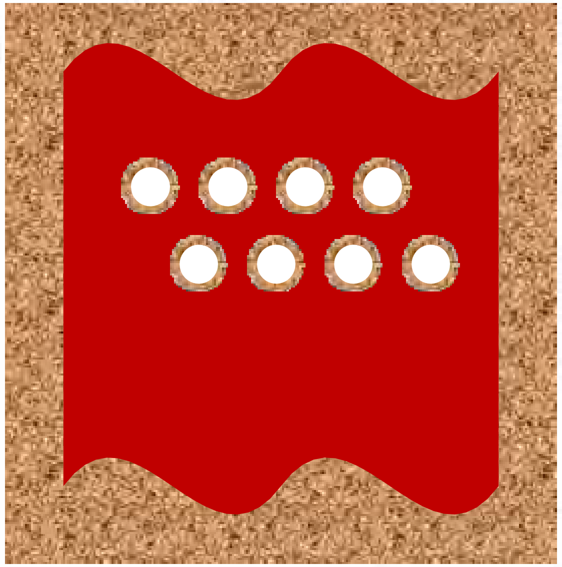


- *Rigid/Flex Transition edges may have sharp edges. The fillet precludes Conductors from being cracked when flex circuit is bent at the rigid-flex edge…transfers the bend beyond this edge*
- *Material is a two-part epoxy (catalyst & hardener). "Flexible Formulation" is the preferred mixture (has elasticity)*
- *Material is typically hand applied with a syringe. Typical Bead width = .030-.090"*

PAD ONLY / BUTTON PLATING



result after copper plating

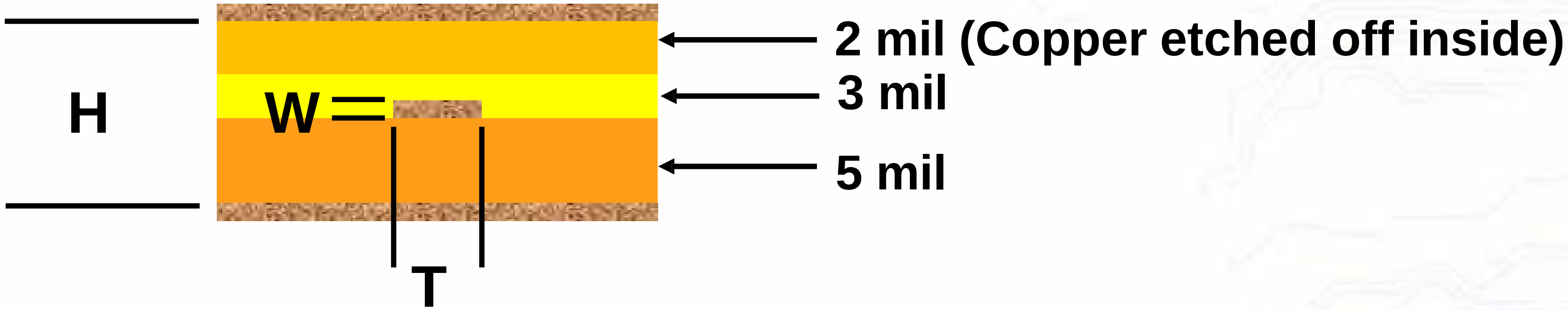


Photoresist image for electrolytic copper plating the holes

- *Technique is typically used on Type 2 circuitry when maximum flexibility is required (NO Electrolytic Copper is added to conductor surfaces)*
- *After electroless copper, a photoresist image is applied exposing the Holes and a small annular ring on the substrate surface. Only this area will receive electrodeposited copper.*
- *After Button Plating, Photoresist is stripped and re-applied to produce circuit image*

ELECTRICAL

IMPEDANCE (STRIPLINE SYMMETRICAL)

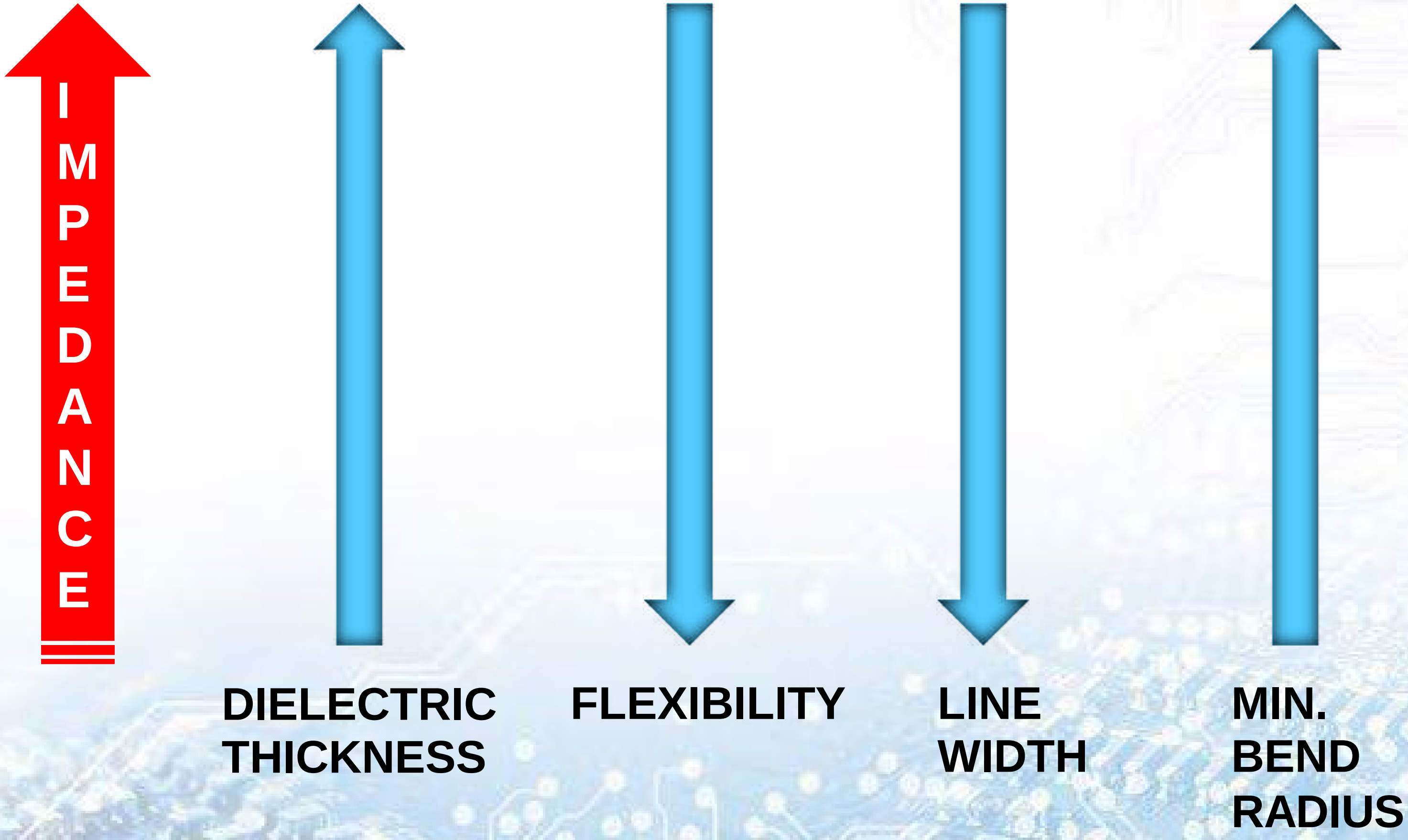


Trace Thickness	*T = .0006”*
Substrate Height	*H = .010”*
Trace Width	*w = .005”*
Substrate	*Er = 3.2”*

Impedance = ~50 OHMS

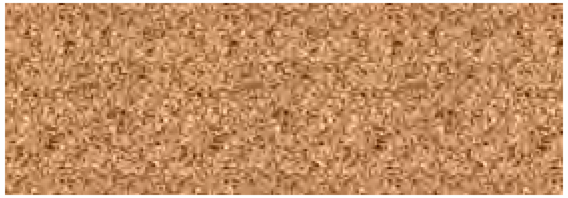
*For Reference only

IMPEDANCE IMPACT



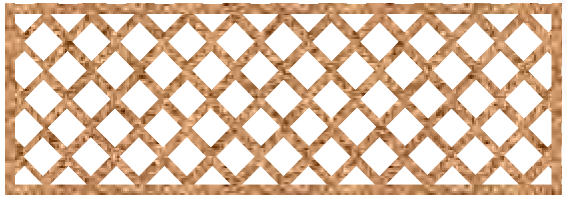
***Stripline will also cause flex layers to be "bonded"**

COPPER PLANE (SHIELDING OPTIONS)



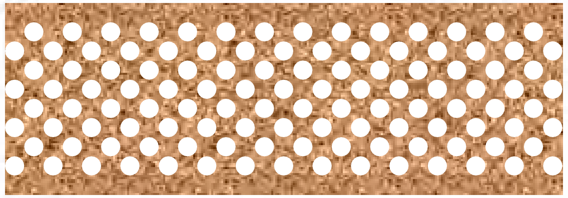
Solid Copper

- Most effective against EMI
- Least Flexible
- Subject to De-Lamination if adhesive to copper bond strength is low
- Thicker Dielectric or Narrower Line Width required to meet Impedance



Cross Hatch

- Increased Flexibility
- Resistant to De-Lamination
- Cracks in Copper can occur at Cross Hatch intersections if flexed repeatedly (stress point)
- Raises Impedance

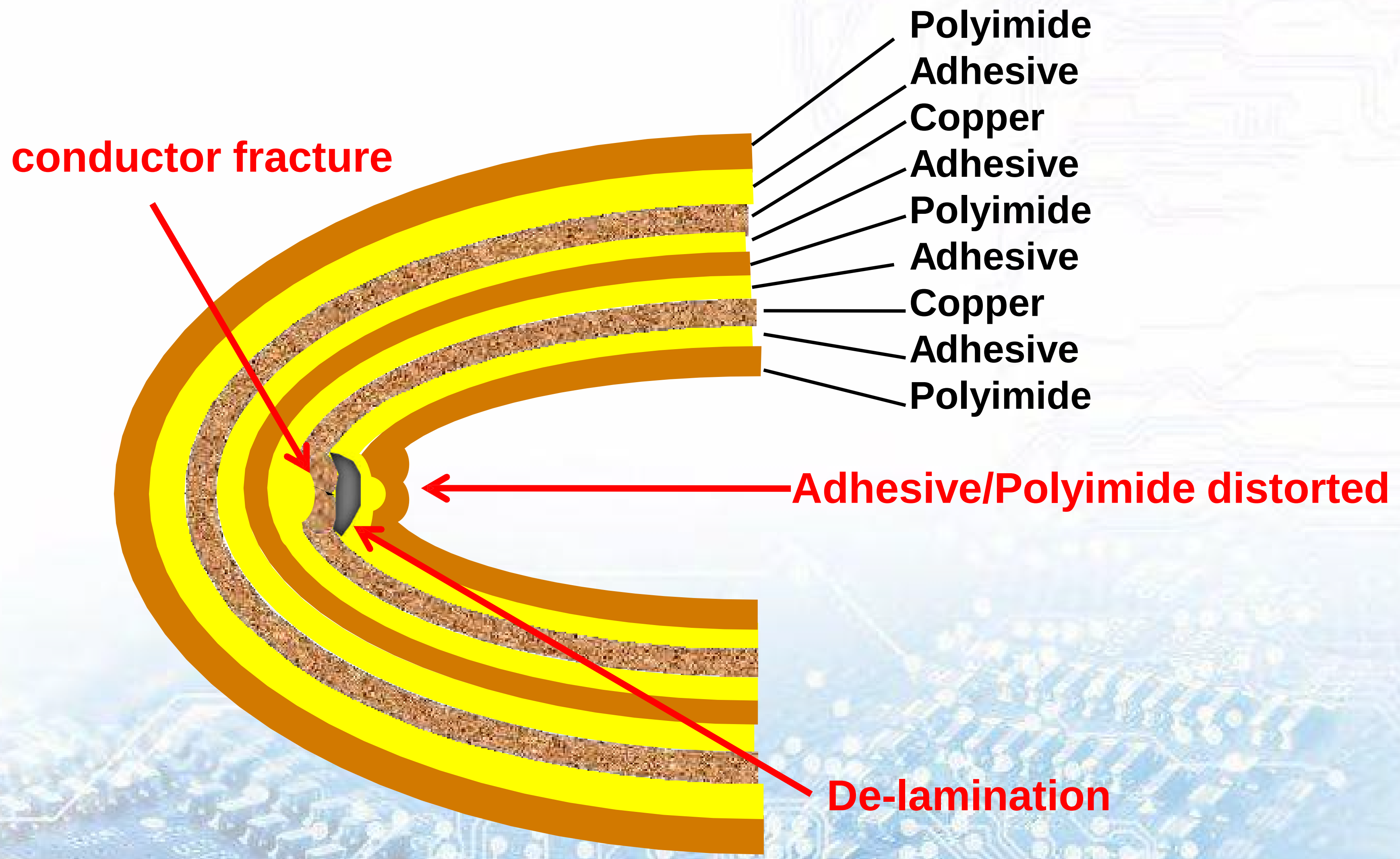


Round Perforations

- Increased Flexibility
- No Stress Points to cause
- Copper to Crack
- Resistant to De-Lamination
- Raises Impedance

MECHANICAL

MINIMUM BEND RADIUS



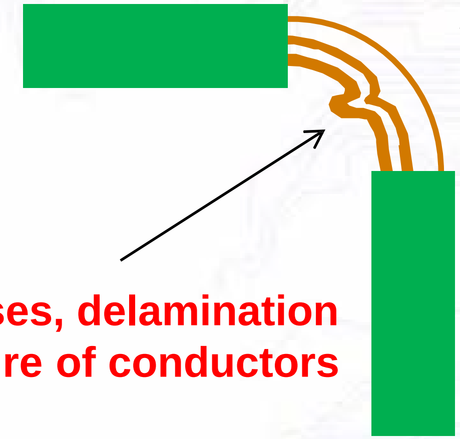
MINIMUM BEND RADIUS *(cont'd)*

- **Even though Flex Circuits are very pliable, there are limits to their flexibility**
- **If Bend Radius is too narrow, delamination occur or conductor breakage can**
- **Minimum Bend Radius Guidelines:**

- ***For Flex Types 1 & 2, the min. bend radius should be at least 6X the overall thickness.***
- ***For Flex Types 3 & 4 (Loose Leaf), the min. bend radius should be at least 12X the overall thickness***
- ***For Flex Types 3 & 4 (Bonded Flex Layers), the min. bend radius should be at least 20X the overall thickness***

BOOKBIND

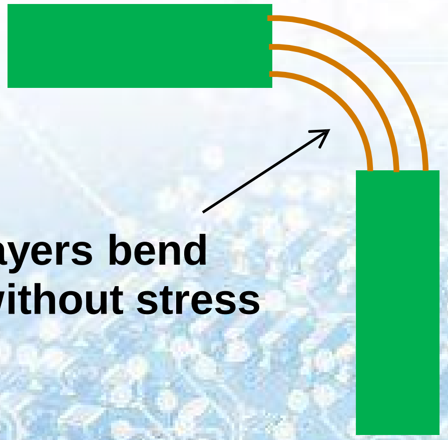
Typical Rigid/Flex Type 4 construction
(8 layers or more)



After 90° bend

wrinkles, creases, delamination
possible fracture of conductors

Typical Rigid/Flex Type 4 with
***Bookbind** construction*
(8 layers or more)



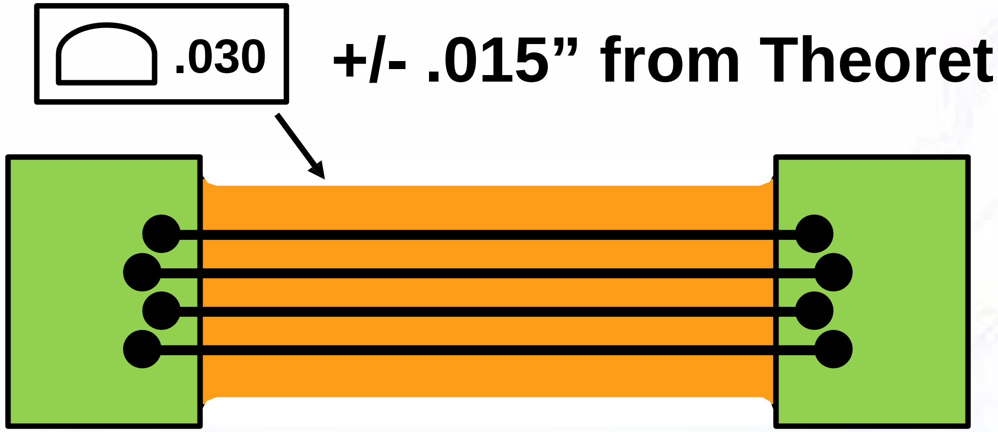
After 90° bend

layers bend
without stress

BOOKBIND (cont'd)

- *Bookbinding will allow the flex layers to bend to the desired radius without the issues noted previously. Technique is to allow the flex layers to fold similar how a book closes.*
- *Should only be considered when all existing methods to satisfactorily accomplish a 90 or 180° (most common) bends are exhausted. Adds significant cost to the manufacturing process.*
- *Requires "lengthening" of the artwork in the flex area. The amount of lengthening depends on:*
  - *Whether Bend is 90 or 180° (180° will need twice the length as 90°)*
  - *Number of flex layers.*
- *Manufacturing process is extremely difficult due to the "hump" created in the panel. Processing concerns with Lamination, Photoresist application, Imaging, Drilling, Plating, HASL if applicable, etc.*

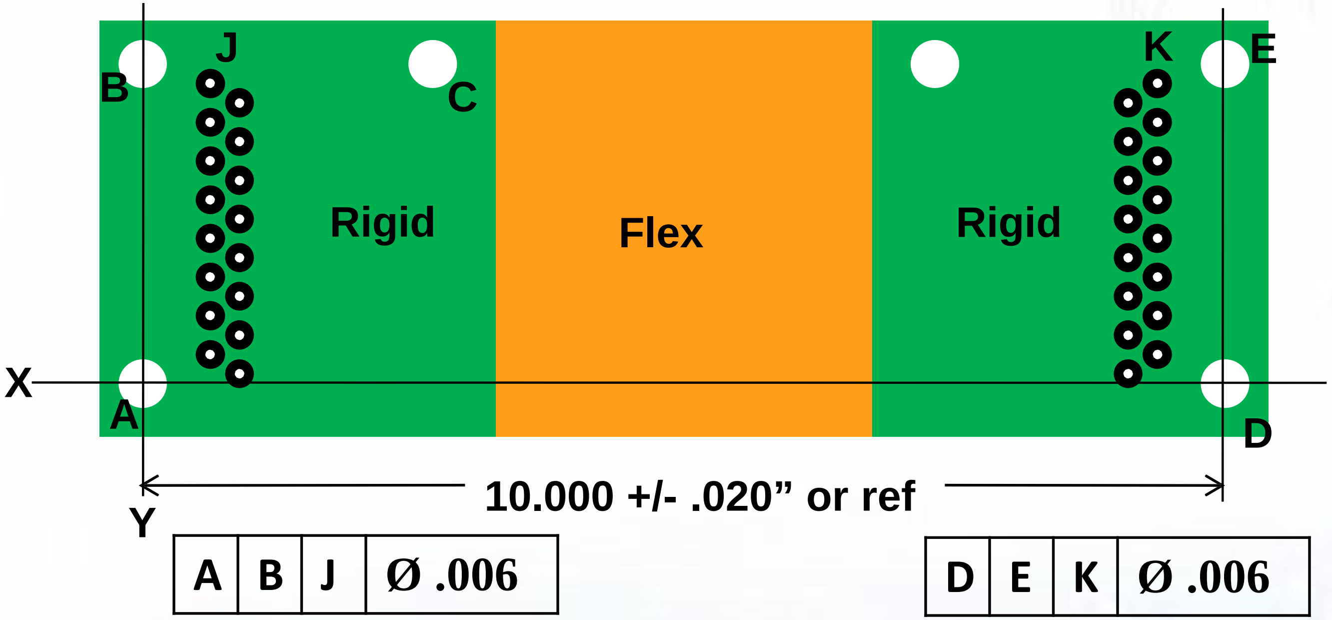
FLEX PROFILE EDGE TOLERANCE



+/- .015” from Theoretical

Tighter Tolerances may require N/C Routing or Laser
Must minimize Edge Roughness

RIGID/FLEX HOLE TO HOLE TOLERANCE



- *Hole locations inside rigid section can be held to typical rigid true hole positions (.005-.010")*
- *Across the flexible section (rigid to rigid) these tolerances cannot be held due to the flexible material may shrink or have slight distortions when in an un-restrained condition*
- *Preferred practice is dimension datum holes across the rigid sections with "loose" or "reference" dimensions.*

WHAT ARE THE DESIGN NEEDS?

ENVIRONMENTAL CONDITIONS & FUNCTIONAL NEEDS

- Fabrication Specification (i.e. IPC 6013) Class 1, 2 or 3
- Flex Circuit Type = 1, 2, 3, or 4
- Application Environment (Space, Sea, Automotive, etc.)
- Operating Temperature Range and Duration
- Thermal Cycle Requirements (if any)
- “Flex to Install” or “Dynamic Flexing” Application (# of cycles and bend method)
- Minimum Bend Radius
- UL Rating
- RoHS

ENVIRONMENTAL CONDITIONS & FUNCTIONAL NEEDS *(cont'd)*

- Electrical Requirements
  - Impedance
  - Shielding
    - EMI (Top & Bottom, 360°
    - Cross Stitch
    - Silver Epoxy
  - Power
  - Signal Integrity (Operating Frequency; Signal Loss)
- Final Finish
- Lead Free Component Assembly

SAMPLE PRINT NOTES

- Fabricate IAW IPC 6013 Class 1, 2 or 3
- Materials (see material pages)
  - Include Material Stackup
  - Pouching is permissible but shall have no impact to flex section
- RoHS required
- UL94V-0 required
- Overall Thickness .XXX” ± .XXX”
- Minimum Conductor Width = .XXX”
- Minimum Conductor Spacing = .XXX”
- 50 Ohm ± 10% Impedance required for layers

SAMPLE PRINT NOTES *(cont'd)*

- Vias may be plugged
- Solder Mask IAW IPC-SM-840 (Solder Mask over Bare Copper) Color Green
- Legend Top & Bottom using White Ink
- Final Finish = ENIG per IPC 4552
- Include Mechanical Tolerances in appropriate Block
- Copper Grain Direction (if applicable)