Results of Fabrication DOE for DuPont Pyralux TK®, A Low Dielectric, Thin Flexible Circuit Material

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From the first time we heard of new thin, low Dk, flex laminate material from DuPont we were excited. The material is what is now known, and commercially available, as DuPont's Pyralux TK®. Working with DuPont on the development we called the material by a code name that we used so often amongst ourselves that now it is difficult to refer to it by its commercial name: Pyralux TK®. For the benefit of the reader, however, I will indulge herein by using the term "TK"®. And in the process hope to explain why we remain very excited about the opportunities that his new material provides the flexible circuit manufacturer.

When first approached by DuPont in the summer of 2009 about beta testing TK® we were most concerned about how the material would react through our standard flex circuit fabrication process. We assumed that DuPont had developed the material thoroughly and that the electrical properties promoted where accurate. But, as veteran flex circuit techies we live in fear of the four-letter word "Teflon"® - and the history that follows that material in flex circuit circles. So, we set out to develop a DOE (design of experiment) that would not only test the material against our standard process, but also against other common flex circuit laminates.

We designed the experiment as a "blind study" to follow an actual "live" part through the shop – a double-sided construction with a differential impedance requirement. We ran everything as one Master Production Lot, but for experimentation purposes separated the types into sub-Lots. The part "as designed and ordered by our customer" served as a Control Lot (which we had made many times before). Along with the Control Lot we created 8 distinct Test Lots each of 3 sheets of 18" X 24" (See Figure 1).

Table 1

Lot No.	Material	Description	Sheet Qty
#1 – AP – 2	AP8525	½ oz. copper both sides of 2 mil Kapton®, adhesive-less	3
#2 – FR – 2	FR8525	½ oz. copper both sides of 2 mil Kapton®, bonded with flame retardant acrylic adhesive	3
#3 – LF – 2	LF8525	½ oz. copper both sides of 2 mil Kapton®, bonded with modified acrylic adhesive	3
#4 – TK – 2	TK8525	½ oz. copper both sides of 2 mil TK®	3
#5 – AP – 3	AP8535	½ oz. copper both sides of 3 mil Kapton®, adhesive-less	3
#6 – FR – 3	FR8535	½ oz. copper both sides of 3 mil Kapton®, bonded with flame retardant acrylic adhesive	3
#7 – LF – 3	LF8535	½ oz. copper both sides of 3 mil Kapton®, bonded with modified acrylic adhesive	3
#1 – TK – 3	TK*535	½ oz. copper both sides of 3 mil TK®	3

We have plenty of experience with the Control Lot design as well as with LF®, FR® and AP® style materials. We felt that this would give us the best comparison for the TK® series laminates. On the Shop Traveler we called for Engineering Inspection at the completion of each major operation. Also, we required that all panels in experiment reside in a desiccant cabinet while not in process - as with all of our work.

Next, we designed a system of Inspections that would allow us to understand the materials behavior through the flex circuit process and in comparison to the other styles as well as the electrical performance characteristics. We performed a combination of these Inspections on every panel in every lot immediately after key standard Operations (listed below). It was determined that these Operations would have the greatest potential of affecting laminate material properties and integrity.

- Base Laminate Drill
- Copper Deposition/Flash Plate
- Acid Copper Plate
- Ammonia Etch (including Resist Strip)

- Covercoat Lamination
- HASL (hot air solder level)
- Electrical Test - Impedance
- Final Inspection

The system of Inspections that we designed involved four areas: Visual Inspection, Chemical Inspection, Dimensional Inspection and Impedance Inspection. The intent was to observe the results at different points during the fabrication process and compare the change to the Lot during the flex circuit processing as well as between the different Lots of material styles and thicknesses. Not all Inspections were performed at every Process point – only where they made sense (see Figure 2). The Inspections are:

1. Visual and Cleanliness Inspection.
   a. Observe the panel through a halo lamp for staining, wrinkling, de-lamination, discoloration or any other anomaly.
   b. When appropriate and after chemical cleaning, dip panel in DI water bath and observe typical "water break" and beading pattern.

2. Cross Section Inspection.
   a. Remove and prepare a micro section from one of the coupons on the panel and exam it under a microscope at from 10X to 40X power.

3. Dimensional Inspection
   a. A Panel-Specific Data Point System was designed and implemented on all Lots, including the Control Lot. The intent was to gauge material stability during processing. (See Figure 3).
   b. The measurements to be made are from the datum to each of the 8 holes and recorded as "X" and "Y" positional data.

4. Impedance Inspection
   a. Coupon measurement of differential impedance structure using Polar CITS 800s (controlled impedance test system).

Table 2

Key Operation	**Visual & Cleanliness**	**Cross Section**	**Dimensional**	**Impedance**
Base Laminate Drill	Yes	Yes	Yes	No
Copper Dep/Flash	Yes	Yes	Yes	No
Acid Copper Plate	Yes	Yes	No	No
Ammonia Etch	Yes	No	Yes	No
Covercoat Lam	Yes	No	Yes	No
HASL	Yes	Yes	Yes	No
ET Impedance	No	No	No	Yes
Final Inspection	Yes	Yes	No	No

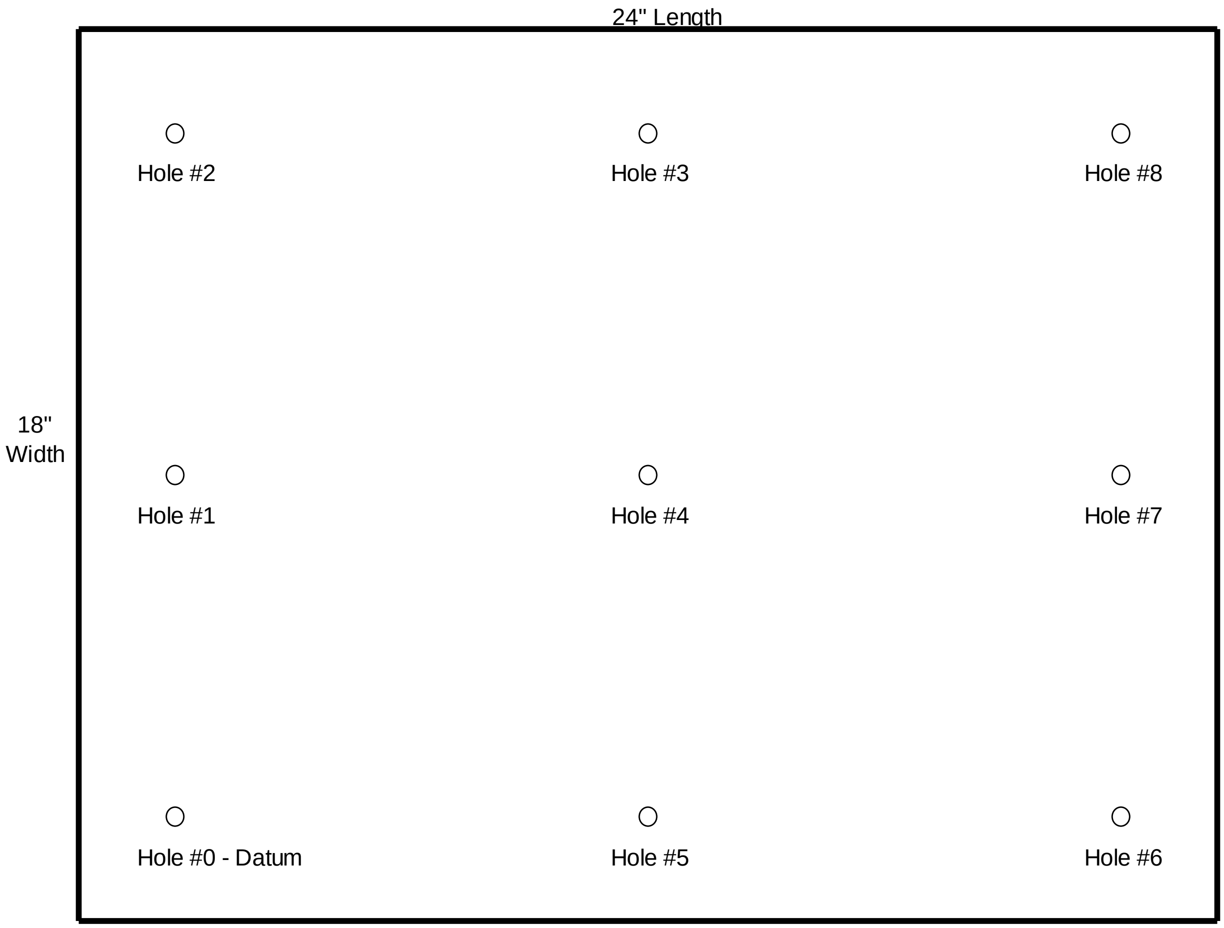

Figure 1

The methods for the Inspections, and results, are as follows:

- Base Laminate Drill. All of the panels in one Lot were packaged and drilled together ("3 high") in one bundle. The Panel-Specific Data Point System was drilled into all bundles with the same NC Program utilizing the appropriate chip load for each of the following new carbide drill tools: .013" Ø, .031"Ø and .040" Ø. All holes in the System are plated thru holes.
    - By Visual Inspection the drill quality was considered very similar and acceptable for all Lots. There was no evidence of excessive burring or slivers.
    - By Cross Section Inspection the hole quality was considered very similar and acceptable for all Lots. Specifically, the Teflon®/Kapton® layers of the TK® were observed to be uniform and clean with no evidence of smear.
    - By Dimensional Inspection all points were found to be near nominal in all materials.

- Copper Deposition/Flash Plate. The Lots were plated through a McDermid "M" Copper Process Line with typical flex circuit dwell times, tank make-ups and solution temperatures.
    - By Visual Inspection the panel quality was considered very similar and acceptable for all Lots. There was no evidence of staining, burning or discoloration. Water beaded evenly on all panels.
    - By Cross Section Inspection the plating integrity was considered to be similar and acceptable for all Lots. There was no evidence of hole wall voids or lack of adhesion. The adherence of the copper plating to the Teflon layers of the TK® material was observed (See Figure 4).
    - By Dimensional Inspection the panel stability was considered to be inconsistent and not similar between the various Lots. The TK® material "moved" a much greater amount than the other materials. As you will notice during other inspections, however, the TK® material movement is consistent and predictable. It also appears that moisture extraction (bake cycles) could reduce this significantly (See Figure 5).

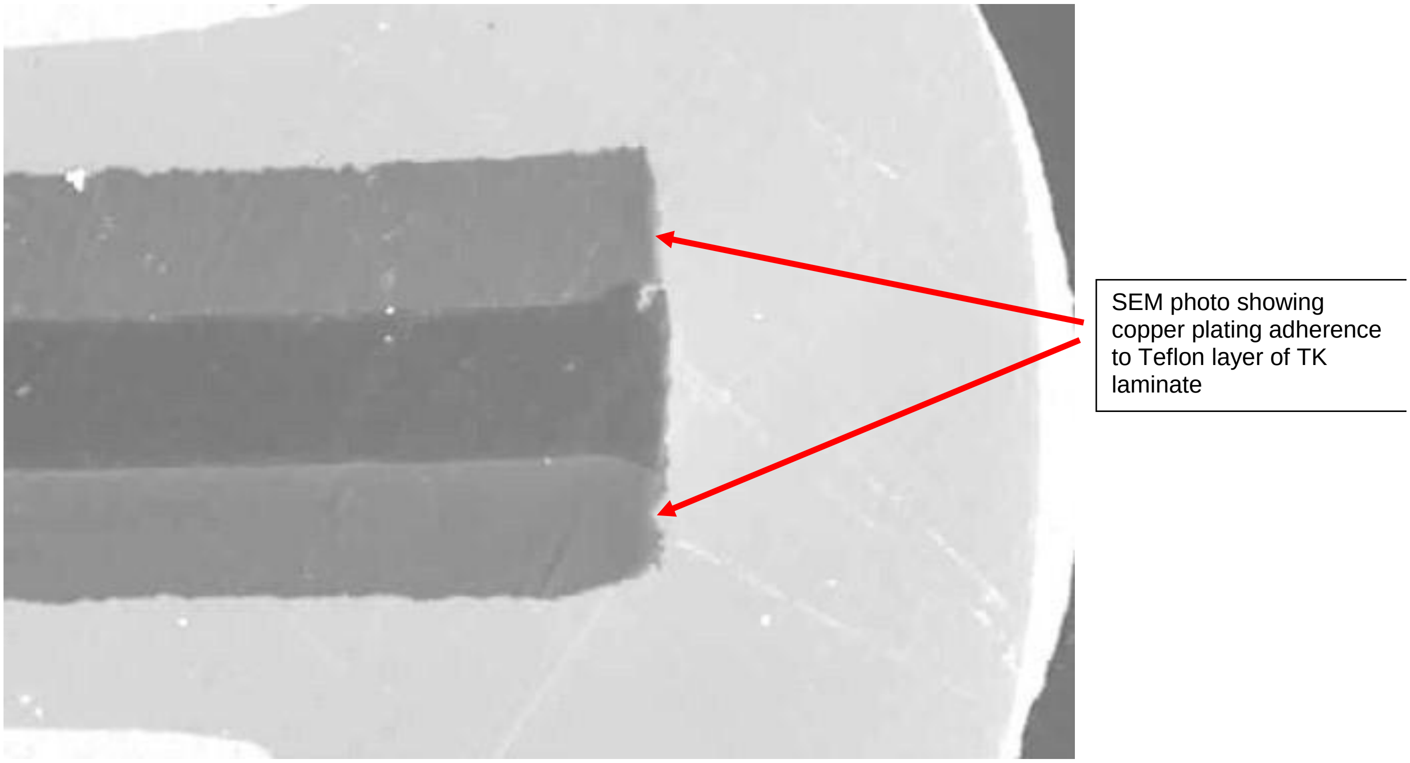

Figure 2

Table 3

After Copper Dep/Flash Plate		
"X" Nominal: 22.0"; "Y" Nominal: 16.0"		
Material	**"X"**	**"Y"**
LF8525	-0.0035	-0.0040
FR8525	-0.0002	-0.0035
AP8525	-0.0067	-0.0082
TK8525	-0.0186	-0.0084
LF8535	-0.0012	-0.0030
FR8535	-0.0072	-0.0049
AP8535	-0.0057	-0.0060
TK8535	-0.0206	-0.0104

- Acid Copper Plating. The Lots were plated in a tank with Bright Acid Copper chemistry at 20 ASF with typical flex circuit dwell times.
  - By Visual Inspection the panel quality was considered very similar and acceptable for all Lots. There was no evidence of staining, burning or discoloration. Water beaded evenly on all panels.
  - By Cross Section Inspection the plating integrity was considered to be similar and acceptable for all Lots. There was no evidence of hole wall voids, inconsistent thickness or lack of adhesion.

- Ammonia Etch. The Lots were run through fully aqueous, ammonia-based develop etch and strip line with typical flex circuit conveyor speeds.

- By Visual Inspection the etch quality was considered very similar and acceptable for all Lots. There was no evidence of undercutting, ragged edges, pitting, staining, or discoloration. Water beaded evenly on all panels.
- By Dimensional Inspection the panel stability was considered to be inconsistent and not similar between the various Lots. The TK® material "moved" a much greater amount than the other materials. As you will notice during other inspections, however, the TK® material movement is consistent and predictable. It also appears that moisture extraction (bake cycles) could reduce this significantly (See Figure 6).

Table 4

After Ammonia Etch		
"X" Nominal: 22.0"; "Y" Nominal: 16.0"		
Material	**"X"**	**"Y"**
LF8525	-0.0012	-0.0011
FR8525	0.0079	-0.0043
AP8525	-0.0012	-0.0037
TK8525	-0.0124	-0.0037
LF8535	0.0042	-0.0009
FR8535	-0.0058	-0.0009
AP8535	-0.0026	-0.0063
TK8535	-0.0270	-0.0156

- Covercoat Lamination. The Lots were all laminated with LF® and FR® covercoats at 250 PSI for 90 minutes at 375° F in a conventional vacuum chamber press with double-sided hydraulic lamination makeup.
  - By Visual Inspection the lamination quality was considered very similar and acceptable for all Lots. There was no evidence of a lack of lamination, wrinkling, staining, burning or discoloration. Water beaded evenly on all panels.
  - By Dimensional Inspection the panel stability was considered to be inconsistent and not similar between the various Lots. The TK® material "moved" a greater amount than the other materials and in the opposite direction. As you will notice during other inspections, however, the TK® material movement is consistent and predictable. It also appears that regular moisture extraction (bake cycles) could reduce this significantly (See Figure 7).

Table 5

After Covercoat Lamination		
“X” Nominal: 22.0”; “Y” Nominal: 16.0”		
Material	**“X”**	**“Y”**
LF8525	0.0018	-0.0041
FR8525	0.0107	-0.0054
AP8525	0.0025	-0.0061
TK8525	-0.0063	-0.0051
LF8535	0.0061	-0.0015
FR8535	-0.0039	-0.0043
AP8535	-0.0019	-0.0037
TK8535	-0.0219	-0.0134

- HASL (hot air solder level). The Lots were pre-baked for 4 hours at 225°F and then processed through a horizontal HASL machine set at typical flex circuit speeds and temperatures.
    - By Visual Inspection the soldering quality was considered very similar and acceptable for all Lots. There was no evidence of blistering, delamination, wrinkling, staining, burning or discoloration. Water beaded evenly on all panels.
    - By Dimensional Inspection the panel stability was considered to be inconsistent and not similar between the various Lots. The TK® material “moved” a greater amount than the other materials and in the opposite direction. It is expected that the negative direction movement of the TK material is due to the presence of high heat at the HASL Operation and is a compensation for previously absorbed moisture. As you will notice during other inspections, however, the TK® material movement is consistent and predictable. It also appears that regular moisture extraction (bake cycles) could reduce this significantly (See Figure 8).

Table 6

After HASL (hot air solder level)		
"X" Nominal: 22.0"; "Y" Nominal: 16.0"		
Material	**"X"**	**"Y"**
LF8525	0.0092	-0.0015
FR8525	0.0153	-0.0028
AP8525	0.0044	-0.0066
TK8525	-0.0031	-0.0057
LF8535	0.0127	0.0028
FR8535	0.0046	-0.0022
AP8535	0.0003	-0.0039
TK8535	-0.0144	-0.0114

- Electrical Test – Impedance. The Lots were subjected to measurement of the characteristic impedance of the differential impedance coupons using a Polar Controlled Impedance Test System, Model CITS800s2. The differential pair trace pitch is 0.013” and trace widths as shown in the Chart in Figure 8.

- By Electrical Test the impedance of the panels in each Lot was considered to vary significantly from Lot to Lot (depending upon material type). The Control Lot was found to be acceptable and all other Lots were for experimentation purposes only. (See Figure 9).

Table 7

IMPEDANCE COUPON			
Panel Number	Trace Width (mils)	Average Imp. Value Coupon 1/ Coupon 2	Dielectric Thickness
A-1	6.00	72.28 / 72.21	.002"
A-2	6.00	72.58 / 74.56	.002"
A-3	6.00	72.41 / 71.02	.002"
B-1	5.50	104.28 / 107.27	.004"
B-2	5.50	105.64 / 107.90	.004"
B-3	5.50	104.86 / 104.65	.004"
C-1	5.50	107.85 / 110.30	.004"
C-2	5.50	107.39 / 109.39	.004"
C-3	5.50	109.42 / 111.74	.004"
D-1	5.50	77.56 / 82.31	.002"
D-2	6.50	77.49 / 79.57	.002"
D-3	6.00	77.66 / 77.19	.002"
E-1	6.00	87.90 / 88.33	.003"
E-2	6.00	88.35 / 90.73	.003"
E-3	5.50	22.68*** / 89.95 (etch defect – short)	.003"
F-1	5.00	121.75 / 122.30	.005"
F-2	5.50	112.91 / 116.30	.005"
F-3	5.50	111.02 / 115.79	.005"
G-1	5.50	110.83 / 115.13	.005"
G-2	5.50	112.31 / 114.54	.005"
G-3	5.00	112.15 / 114.72	.005"
H-1	6.00	99.45 / 99.46	.003"
H-2	6.00	98.86 / 99.40	.003"
H-3	5.50	104.17 / 98.54	.003"

- Final Inspection and Certification. The Lots were subjected to standard flex circuit MIL-P-50884E/2 acceptance criteria and inspection, including Thermal Stress and Rework Simulation on the IPC-2223 coupons.
- There was no evidence indicating a poor plating bond to the TK® material or delamination of the conventional covercoats to the TK® substrate.
    - By Visual Inspection the finished parts were considered very similar and acceptable for all Lots. There was no evidence of delamination, wrinkling, staining, or discoloration. Water beaded evenly on all panels.

- By Cross Section Inspection the through hole integrity was considered to be similar and acceptable for all Lots. There was no evidence of hole wall voids, inconsistent thickness or lack of adhesion. Specifically, there was also no evidence of any lamination deficiency in bond between the TK base laminate and the LF® covercoats.

In summary, we found the TK® material to run through our flex circuit process no differently than the LF®, AP® or FR® style laminates in regard to material durability, handling, cleanliness and general resistance to chemicals. We did notice a difference in the dimensional stability of the TK® materials. However, we found this increased movement of the TK® laminate to be consistent, predictable and apparently susceptible to moisture extraction (heat cycles). In reviewing the mechanical data collected, the TK® Material has exhibited a distortion (shrinkage) of approximately .001" per inch.
In compensating for this, manufacturers should allow for a conservative panelization scheme to maximize panel stability. Artwork pattern layers and N.C. programs can also be scaled to compensate for this distortion with the concept that the variation within the distortion will be minimal with consistent processing parameters. It is further expected that, in a typical production scenario, the TK® material will not only be engineered through photo tooling compensation procedures, but also benefit from the insertion of regular bake cycles for moisture extraction, to result in substrate performance with much the same results as LF®, AP® and FR® laminates.

Meanwhile, apparently the dielectric constant of the TK® material yielded a much higher value for the same width signal trace on the other laminates of the same thickness. So, this leads us to believe that there are many potential uses for the TK® material in high signal integrity flex circuit applications.

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IPC APEX/EXPO CONFERENCE

April 2011

Results of Fabrication DOE (design of experiment) for a Newly Developed Thin, Low Dielectric Flexible Circuit Laminate Material

Mr. Al Wasserzug

VULCAN FLEX CIRCUIT CORPORATION

Experiment Development

- Manufacturer sampled new flouropolymer/polyimide material ("new material")
- Picked an ongoing production design with 75 Ωimpedance requirement
- The standard (legacy) build became the control Sample Lot
- Additionally developed 2 comparison Sample Lots of similar/common materials
- Covercoats in all cases were 1 mil un-reinforced polyimide film with either modified acrylic adhesive or a flame retardant adhesive

BASE LAMINATE MATERIAL SAMPLES (LOTS)			
Sample Lot #	**Designation**	**Description**	**Quantity**
2184-A	control	½ ox. copper both sides of 2 mil un-reinforced polyimide film, adhesive-less	3
2184-B	comparison	½ ox. copper both sides of 2 mil un-reinforced polyimide film, flame retardant adhesive	3
2184-C	comparison	½ ox. copper both sides of 2 mil un-reinforced polyimide film, modified acrylic adhesive	3
2184-D	specimen	½ ox. copper both sides of 2 mil structure (Teflon/un-reinforced polyimide film/Teflon), adhesive-less	3
2184-E	control	½ ox. copper both sides of 3 mil un-reinforced polyimide film, adhesive-less	3
2184-F	comparison	½ ox. copper both sides of 3 mil un-reinforced polyimide film, flame retardant adhesive	3
2184-G	comparison	½ ox. copper both sides of 3 mil un-reinforced polyimide film, modified acrylic adhesive	3
2184-H	specimen	½ ox. copper both sides of 3 mil structure (Teflon/un-reinforced polyimide film/Teflon), adhesive-less	3

Experiment Development

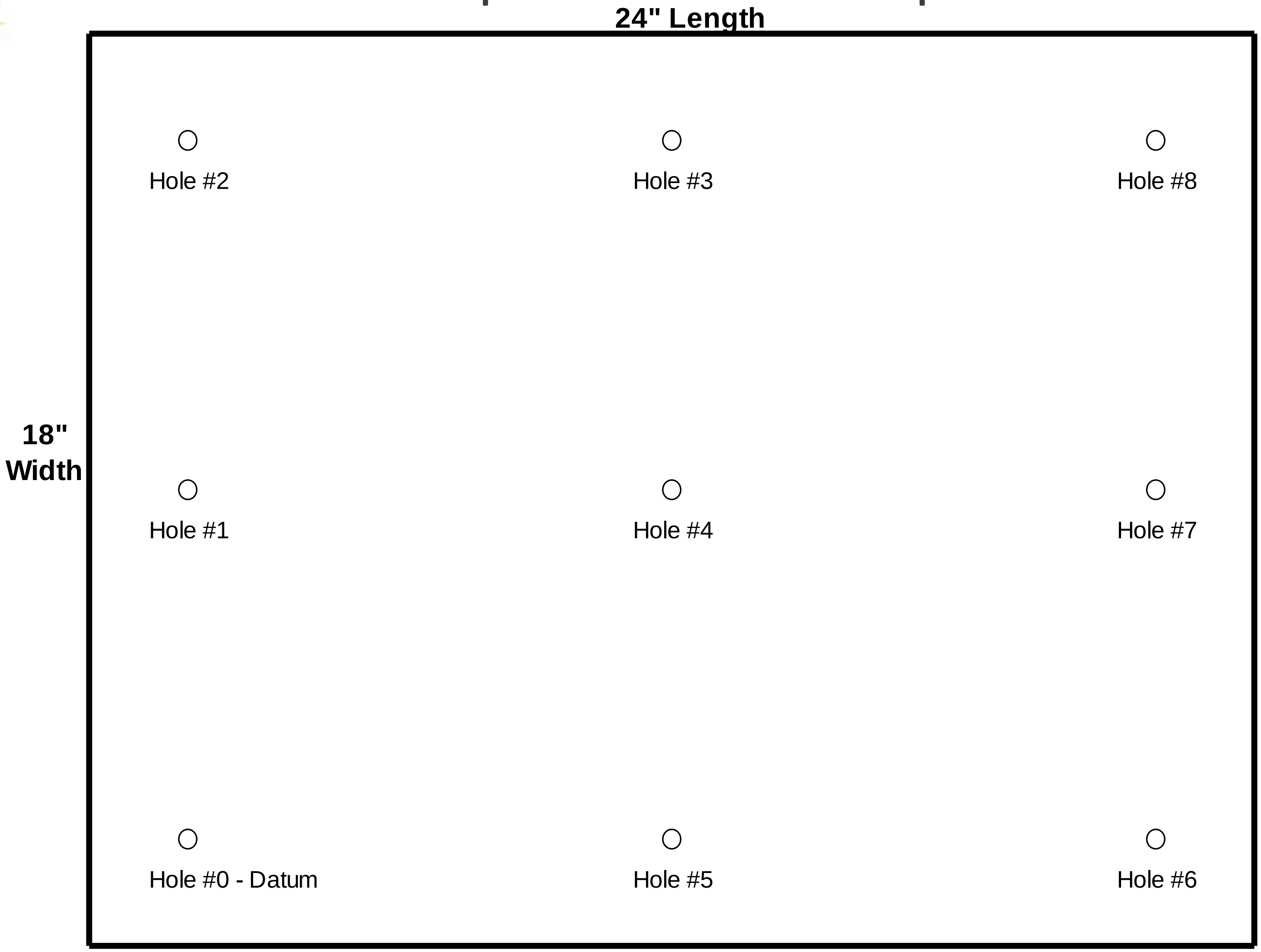
- Selected Observation (Inspection) points based on processes most likely to affect the performance of the material.
  - Base Laminate Drill
  - Copper Deposition/Flash Plate
  - Acid Copper Plate
  - Ammonia Etch (including Resist Strip)
  - Covercoat Lamination
  - HASL (hot air solder level)
  - Electrical Test - Impedance
  - Final Inspection

Key Operation	Visual & Cleanliness	Cross Section	Dimensional	Impedance
Base Laminate Drill	Yes	Yes	Yes	No
Copper Dep/Flash	Yes	Yes	Yes	No
Acid Copper Plate	Yes	Yes	No	No
Ammonia Etch	Yes	No	Yes	No
Covercoat Lam	Yes	No	Yes	No
HASL	Yes	Yes	Yes	No
ET Impedance	No	No	No	Yes
Final Inspection	Yes	Yes	No	No

Experiment Development

- Developed standard measurement methods designed to result in data that can easily be compared and reveal trends in the material performance.
  - Visual & Cleanliness
    - Observe the panel through a halo lamp for de-lamination, staining, wrinkling, discoloration or any other anomaly
    - When appropriate and after chemical cleaning, dip panel in DI water bath and observe beading pattern.
  - Cross Section Analysis
    - Remove and prepare a micro section from one of the coupons on the panel and exam it under a microscope at from 10X to 40X power
  - Dimensional Measurements
    - A Panel-Specific Data Point System was developed for all samples. The intent was to gauge material stability during processing
    - The measurements to be made are from the datum to each of the 8 holes and recorded as “X” and “Y” positional data.
  - Impedance Measurements
    - Coupon measurement of differential impedance structure using TDR

Experiment Development



Panel-Specific Data Point System

Results of Observations
Base Laminate Drill

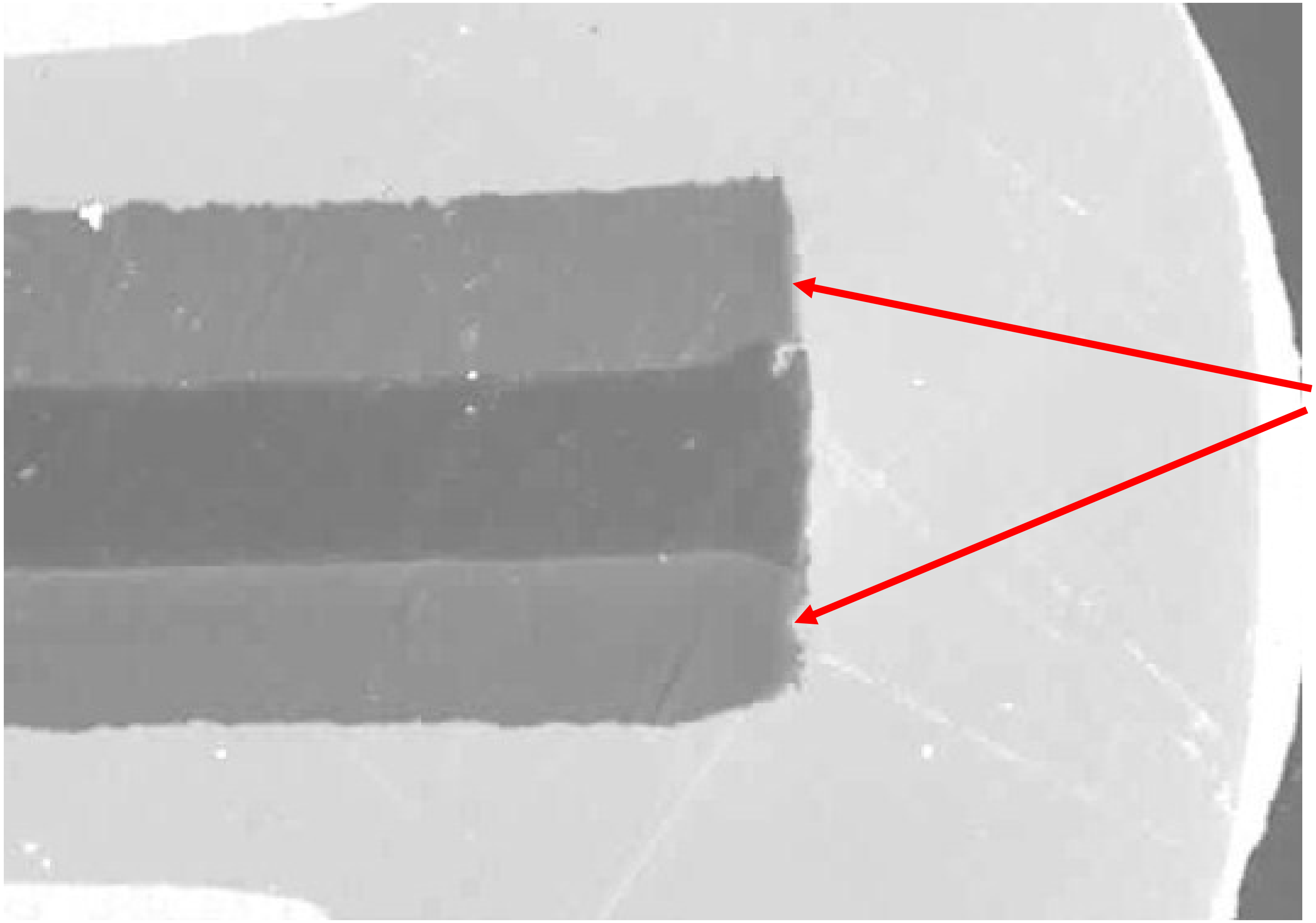
- Base Laminate Drill. All of the panels in one Sample Lot were packaged and drilled together (3 high) in one bundle. The Panel-Specific Data Point System was drilled into all bundles with the same NC Program utilizing the appropriate chip load for each of the following new carbide drill tools: .013” (0.33 mm) Ø, .031” (0.79 mm) Ø and .040” (1.01 mm) Ø. All holes in the System are subsequently plated through.

  - By Visual Inspection the drill quality was considered very similar and acceptable for all samples. There was no evidence of excessive burring or slivers.
  - By Cross Section Inspection the hole quality was considered very similar and acceptable for all samples. Specifically, the structure layers of the new material were observed to be uniform and clean with no evidence of smear.
  - By Dimensional Inspection all points were found to be near nominal in all materials.

Results of Observations
Copper Deposition/Flash Plate

- Copper Deposition/Flash Plate. The Samples were plated through a standard Copper Process Line with typical flex circuit dwell times, tank make-ups and solution temperatures.
    - By Visual Inspection the panel quality was considered very similar and acceptable for all samples. There was no evidence of staining, burning or discoloration. Water beaded evenly on all panels.
    - By Cross Section Inspection the plating integrity was considered to be similar and acceptable for all samples. There was no evidence of hole wall voids or lack of adhesion. The adherence of the copper plating to the structure plies of the new material (specifically the flouropolymer plies) was observed (see photo next slide).
    - By Dimensional Inspection the stability of the various samples was predictable, but not zero for the flouropolymer based materials. The new material “moved” a much greater amount than the other materials. As you will notice during other inspections, however, the new material movement is consistent and predictable. It also appears that moisture extraction (bake cycles) could reduce this significantly.

Results of Observations
Copper Deposition/Flash Plate



SEM photo showing copper plating adherence to the flouropolymer plies of new material structure

Results of Observations
Copper Deposition/Flash Plate

After Copper Deposition/Flash Plate		
"X" Nominal: 22.0"; "Y" Nominal: 16.0"		
Material	**"X"**	**"Y"**
Sample Lot 2184-A (control)	-0.0067	-0.0082
Sample Lot 2184-B	-0.0002	-0.0035
Sample Lot 2184-C	-0.0035	-0.0040
Sample Lot 2184-D (specimen)	-0.0186	-0.0084
Sample Lot 2184-E (control)	-0.0057	-0.0060
Sample Lot 2184-F	-0.0072	-0.0049
Sample Lot 2184-G	-0.0012	-0.0030
Sample Lot 2184-H (specimen)	-0.0206	-0.0104

Results of Observations
Acid Copper Plating

- Acid Copper Plating. The samples were plated in a tank with Bright Acid Copper chemistry at 20 ASF with typical flex circuit dwell times.

    - Visual Inspection the panel quality was considered very similar and acceptable for all samples. There was no evidence of staining, burning or discoloration. Water beaded evenly on all panels.
    - Cross Section Inspection the plating integrity was considered to be similar and acceptable for all samples. There was no evidence of hole wall voids, inconsistent thickness or lack of adhesion.

Results of Observations
Ammonia Etch

- Ammonia Etch. The samples were processed through a fully aqueous, ammonia-based, develop, etch and strip line with typical flex circuit conveyor speeds.
  - By Visual Inspection the etch quality was considered very similar and acceptable for all samples. There was no evidence of undercutting, ragged edges, pitting, staining, or discoloration. Water beaded evenly on all panels.
  - By Dimensional Inspection the stability of the various samples was predictable, but not zero for the flouropolymer based materials. The new material “moved” a much greater amount than the other materials. As you will notice during other inspections, however, the new material movement is consistent and predictable. It also appears that moisture extraction (bake cycles) could reduce this significantly.

Results of Observations
Ammonia Etch

After Ammonia Etch		
"X" Nominal: 22.0"; "Y" Nominal: 16.0"		
Material	**"X"**	**"Y"**
Sample Lot 2184-A (control)	-0.0012	-0.0037
Sample Lot 2184-B	0.0079	-0.0043
Sample Lot 2184-C	-0.0012	-0.0011
Sample Lot 2184-D (specimen)	-0.0124	-0.0037
Sample Lot 2184-E (control)	-0.0026	-0.0063
Sample Lot 2184-F	-0.0058	-0.0009
Sample Lot 2184-G	0.0042	-0.0009
Sample Lot 2184-H (specimen)	-0.0270	-0.0156

Results of Observations
Covercoat Lamination

- Covercoat Lamination. The samples were all laminated with the covercoats at 250 PSI for 90 minutes at 375^{o} F in a conventional vacuum chamber press with double-sided hydraulic lamination makeup.

  - By Visual Inspection the lamination quality was considered very similar and acceptable for all samples. There was no evidence of a lack of lamination, wrinkling, staining, burning or discoloration. Water beaded evenly on all panels.
  - By Dimensional Inspection the stability of the various samples was predictable, but not zero for the flouropolymer based materials. The new material "moved" a greater amount than the other materials and in the opposite direction. As you will notice during other inspections, however, the new material movement is consistent and predictable. It also appears that regular moisture extraction (bake cycles) could reduce this significantly.

Results of Observations
Covercoat Lamination

After Covercoat Lamination		
“X” Nominal: 22.0”; “Y” Nominal: 16.0”		
Material	**“X”**	**“Y”**
Sample Lot 2184-A (control)	0.0025	-0.0061
Sample Lot 2184-B	0.0107	-0.0054
Sample Lot 2184-C	0.0018	-0.0041
Sample Lot 2184-D (specimen)	-0.0063	-0.0051
Sample Lot 2184-E (control)	-0.0019	-0.0037
Sample Lot 2184-F	-0.0039	-0.0043
Sample Lot 2184-G	0.0061	-0.0015
Sample Lot 2184-H (specimen)	-0.0219	-0.0134

Results of Observations
HASL (hot air solder level)

- HASL (hot air solder level). The samples were pre-baked for 4 hours at 225º F and then processed through a horizontal HASL machine set at typical flex circuit speeds and temperatures.

  - By Visual Inspection the soldering quality was considered very similar and acceptable for all samples. There was no evidence of blistering, delamination, wrinkling, staining, burning or discoloration. Water beaded evenly on all panels.
  - Dimensional Inspection the stability of the various samples was predictable, but not zero for the flouropolymer based materials. The new material "moved" a greater amount than the other materials and in the opposite direction. It is expected that the negative direction movement of the new material is due to the presence of high heat at the HASL Operation and is a compensation for previously absorbed moisture. As you will notice during other inspections, however, the new material movement is consistent and predictable. It also appears that regular moisture extraction (bake cycles) could reduce this significantly.

Results of Observations
HASL (hot air solder level)

After HASL (hot air solder level)		
"X" Nominal: 22.0"; "Y" Nominal: 16.0"		
Material	**"X"**	**"Y"**
Sample Lot 2184-A (control)	0.0044	-0.0066
Sample Lot 2184-B	0.0153	-0.0028
Sample Lot 2184-C	0.0092	-0.0015
Sample Lot 2184-D (specimen)	-0.0031	-0.0057
Sample Lot 2184-E (control)	0.0003	-0.0039
Sample Lot 2184-F	0.0046	-0.0022
Sample Lot 2184-G	0.0127	0.0028
Sample Lot 2184-H (specimen)	-0.0144	-0.0114

Results of Observations
Impedance Testing

- Electrical Test – Impedance. The samples were subjected to measurement of the characteristic impedance of the differential impedance coupons using a Controlled Impedance Test System. The differential pair trace pitch is 0.013” (0.33 mm) and trace widths.
  - Since the laminate materials have very different Dielectric Constant values, there is significant variation in the impedance.
  - Discussion of these differences are covered in the presentation on this work by DuPont.

IMPEDANCE COUPON MEASUREMENTS			
Sample Lot – Panel No.	Trace Width (mils)	Average Impedance Value Coupon 1/Coupon 2	Dielectric Thickness
2184-A-1	6.00	72.28 / 72.21	.002"
2184-A-2	6.00	72.58 / 74.56	.002"
2184-A-3	6.00	72.41 / 71.02	.002"
2184-B-1	5.50	104.28 / 107.27	.004"
2184-B-2	5.50	105.64 / 107.90	.004"
2184-B-3	5.50	104.86 / 104.65	.004"
2184-C-1	5.50	107.85 / 110.30	.004"
2184-C-2	5.50	107.39 / 109.39	.004"
2184-C-3	5.50	109.42 / 111.74	.004"
2184-D-1	5.50	77.56 / 82.31	.002"
2184-D-2	6.50	77.49 / 79.57	.002"
2184-D-3	6.00	77.66 / 77.19	.002"
2184-E-1	6.00	87.90 / 88.33	.003"
2184-E-2	6.00	88.35 / 90.73	.003"
2184-E-3	5.50	22.68*** / 89.95 (etch defect – short)	.003"
2184-F-1	5.00	121.75 / 122.30	.005"
2184-F-2	5.50	112.91 / 116.30	.005"
2184-F-3	5.50	111.02 / 115.79	.005"
2184-G-1	5.50	110.83 / 115.13	.005"
2184-G-2	5.50	112.31 / 114.54	.005"
2184-G-3	5.00	112.15 / 114.72	.005"
2184-H-1	6.00	99.45 / 99.46	.003"
2184-H-2	6.00	98.86 / 99.40	.003"
2184-H-3	5.50	104.17 / 98.54	.003"

Results of Observations

- Final Inspection and Certification. All of the samples were subjected to standard flex circuit MIL-P-50884E/2 acceptance criteria and inspection, including Thermal Stress and Rework Simulation on the IPC-2223 coupons.

- There was no evidence indicating a poor plating bond to the new material or delamination of the conventional covercoats to the new material.

  - Visual Inspection the finished parts were considered very similar and acceptable for all samples. There was no evidence of delamination, wrinkling, staining, or discoloration. Water beaded evenly on all panels.
  - Cross Section Inspection the through hole integrity was considered to be similar and acceptable for all samples. There was no evidence of hole wall voids, inconsistent thickness or lack of adhesion. Specifically, there was also no evidence of any lamination deficiency in bond between the new material and the covercoats.

Summary

In summary, we found the new material to run through our flex circuit process no differently than the control or additional style laminates in regard to material durability, handling, cleanliness and general resistance to chemicals. We did notice a difference in the dimensional stability of the new material. However, we found this increased movement of the new material to be consistent, predictable and apparently susceptible to moisture extraction (heat cycles). In reviewing the mechanical data collected, the new material has exhibited a distortion (shrinkage) of approximately .001” (0.025 mm) per inch.

In compensating for this, manufacturers should allow for a conservative panelization scheme to maximize panel stability. Artwork pattern layers and N.C. programs can also be scaled to compensate for this distortion with the concept that the variation within the distortion will be minimal with consistent processing parameters. It is further expected that, in a typical production scenario, the new material will not only be engineered through photo tooling compensation procedures, but also benefit from the insertion of regular bake cycles for moisture extraction, to result in substrate performance with much the same results as the other commonly used laminates.

Meanwhile, apparently the dielectric constant of the new material yielded a much higher value for the same width signal trace on the other laminates of the same thickness. So, this leads us to believe that there are many potential uses for the new material in high signal integrity flex circuit applications.

Thank You

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