DuPont™ Pyralux® AP-*PLUS*

ALL-POLYIMIDE THICK COPPER-CLAD LAMINATES

An Expanded Family of High-Performance Laminates for Advanced Flexible and Rigid-Flex Printed Circuit Applications

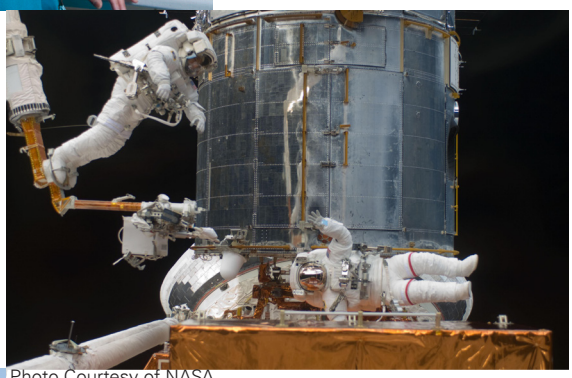


Photo Courtesy of NASA

Product Description

DuPont is extending its portfolio of all-polyimide copper-clad laminates with Pyralux® AP-*PLUS*, building on its leading Pyralux® AP brand all-polyimide copper-clad laminate. Pyralux® AP-*PLUS* laminates feature a core construction of Pyralux® AP dielectric in extended thickness offerings of 7-12 mil (175-250 microns) and greater. Pyralux® AP set the industry standard for high performance laminates when it was introduced in 1996, and with Pyralux® AP- *PLUS*, a new range of greater core thicknesses is now available, offering increased signal integrity and high reliability to provide additional options in meeting circuit needs for a new generation. DuPont™ Pyralux® AP-*PLUS* all-polyimide thick copper-clad laminates are engineered to help OEM designers, fabricators, and assemblers achieve maximum yields and performance in the most demanding flexible and rigid-flex printed circuit designs, such as those used in military, aerospace and medical equipment applications.

Like Pyralux® AP, Pyralux® AP-*PLUS* is a double-sided laminate system of core polyimide bonded to a wide variety of copper types and weights to meet industry standard and specialty design requirements. As a sheet clad offering, fabricators can maximize production yields by choosing Pyralux® AP-*PLUS* in a variety of standard or customized laminate dimensions up to 100" in length, ideal for specialty needs such as satellite or antenna flex.

Most Pyralux® AP-*PLUS* constructions are available with standard delivery times in both small and large commercial volumes to meet initial design qualification needs as well as long-term supply for large multi-year programs.

DuPont™ Pyralux® AP-*PLUS* all-polyimide thick copper-clad laminates Key Features

- Tight overall thickness tolerance for controlled impedance applications
- Expanded design options for manufacturing yields and signal integrity in high-frequency circuits. All-Polyimide laminate cores in 7, 8, 9, 10, and 12 mil thickness. Copper choices from 5 micron to 2 oz.
- Robust all-polyimide performance for demanding high reliability, military, and aerospace applications.
- Fully compatible with industry fabrication processes. IPC 4204/11 certified.
- Available in standard and custom sizing (up to 100" length).
- Commercially available in required long-term volumes and delivery times

Unless otherwise specified, the Pyralux® AP-*PLUS* all-polyimide thick copper-clad laminates constructions listed below are supplied with "R" designated copper (rolled-annealed). Other copper types are available, i.e. electro-deposited ("E"). e.g., Pyralux® AP-*PLUS* 7229E or double-treated copper ("D") e.g. AP-*PLUS* 9171D. Additional unbalanced specialty constructions are available by request. Please contact your DuPont representative for details.

Table 1: DuPont™ Pyralux® AP-*PLUS* Product Offerings*

Product Code	Dielectric Thickness, mil	Cu Thickness, um (oz/ft²)
AP8575	7.0	18 (0.5)
AP9171	7.0	35 (1.0)
AP9272	7.0	70 (2.0)
AP8585	8.0	18 (0.5)
AP9181	8.0	35 (1.0)
AP9282	8.0	70 (2.0)
AP8595	9.0	18 (0.5)
AP9191	9.0	35 (1.0)
AP9292	9.0	70 (2.0)
AP7229	10.0	18 (0.5)
AP7340	10.0	35 (1.0)
AP7375	10.0	70 (2.0)
AP7402	12.0	18 (0.5)
AP7369	12.0	35 (1.0)
AP7378	12.0	70 (2.0)

*Contact us for additional construction needs

Table 2: DuPont™ Pyralux® AP-*PLUS* Typical Material Property Summary

AP-*PLUS* Laminate Property	IPC TM-650 (or other)	7-12 mil Typical Value
Adhesion to Copper (Peel Strength) As fabricated, N/mm (lb/in) After Solder, N/mm (lb/in)	Method 2.4.9	 >1.8 (10) >1.8 (10)
Solder Float at 288°C (550°F)	Method 2.4.13	Pass
Dimensional Stability Method B % Method C %	Method 2.2.4	 -.03 to -.06 -.03 to -.06
Dielectric Thickness Tolerance , %	Method 4.6.2	+/- 5
Dielectric Constant, 1MHz -10 GHz	IPC 2.5.5.3, ASTM 2520C	3.4
Dissipation Factor, 1MHz -10 GHz	IPC 2.5.5.3, ASTM 2520C	0.002
Dielectric Strength, kV/mil	ASTM-D-149	6-7
Volume Resistivity, ohm-cm	Method 2.5.17.1	E17
Surface Resistance, ohms	Method 2.5.17.1	>E16
Moisture and Insulation Res., ohms	Method 2.6.3.2	E11
Moisture Absorption, %	Method 2.6.2	0.8
Tensile Strength, MPa (kpsi)	Method 2.4.19	>345 (>50)
Elongation, %	Method 2.4.19	>50
Initiation Tear Strength, grams	Method 2.4.16	900-1200
Propagation Tear Strength, grams	Method 2.4.17.1	>20
Chemical Resistance, min. %	Method 2.3.2	Pass, >95%
Solderability	IPC-S-804,M.1	Pass
Glass Transition (Tg), °C	----	220
Modulus, kpsi	----	700
In-Plane CTE T<Tg, (ppm/°C)	----	25
In-Plane CTE T>Tg, (ppm/°C)	----	40 (estimated)

Laminate Construction and Benefits of Pyralux® AP-PLUS

The core dielectric in Pyralux® AP-*PLUS* all-polyimide thick copper-clad laminates is designed to provide the maximum electrical and signal integrity benefits available in an all-polyimide thick-clad construction. Unlike typical printed circuit boards that are constructed from various woven fiberglass fabrics strengthened and bound in an epoxy matrix, AP-*PLUS* is a "weave-free" all-polyimide profile providing a smoother surface and homogeneous medium for improved signal integrity.

Figures 1 and 2 illustrate typical circuit traces fabricated with Pyralux® AP-*PLUS*. The homogeneous dielectric core provides designers a consistent dielectric constant for controlled impedance circuit requirements and minimized signal reflection in thick-core applications.

Electrical benefits include:

- signal transmission efficiency
- lower noise
- faster transmission across a wide range of design frequencies

Figure 1: Surface SEM (250X) of 4 mil copper trace in Pyralux® AP-*PLUS* all-polyimide thick copper-clad laminates showing all-polyimide smooth dielectric profile for improved signal integrity.

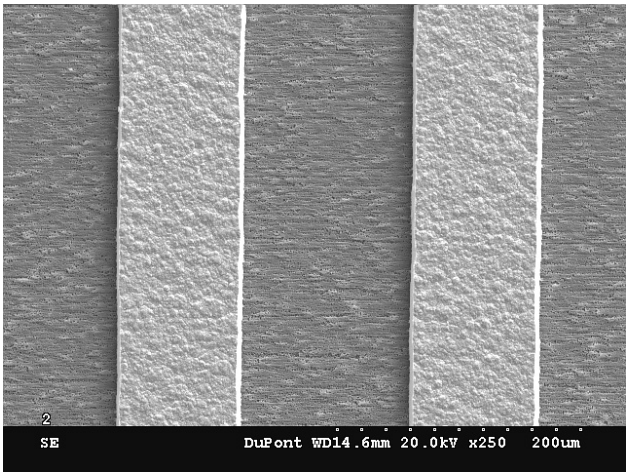
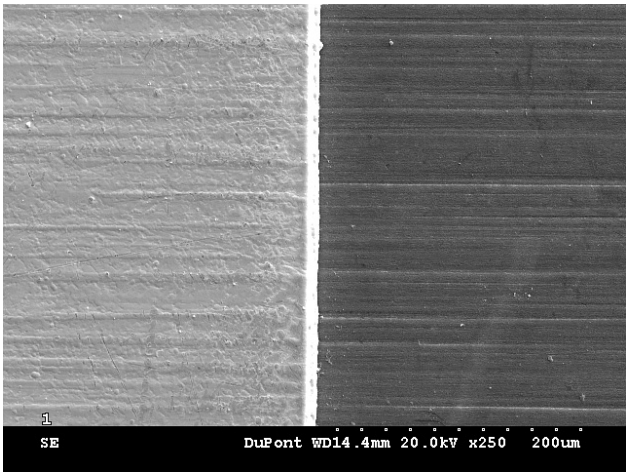
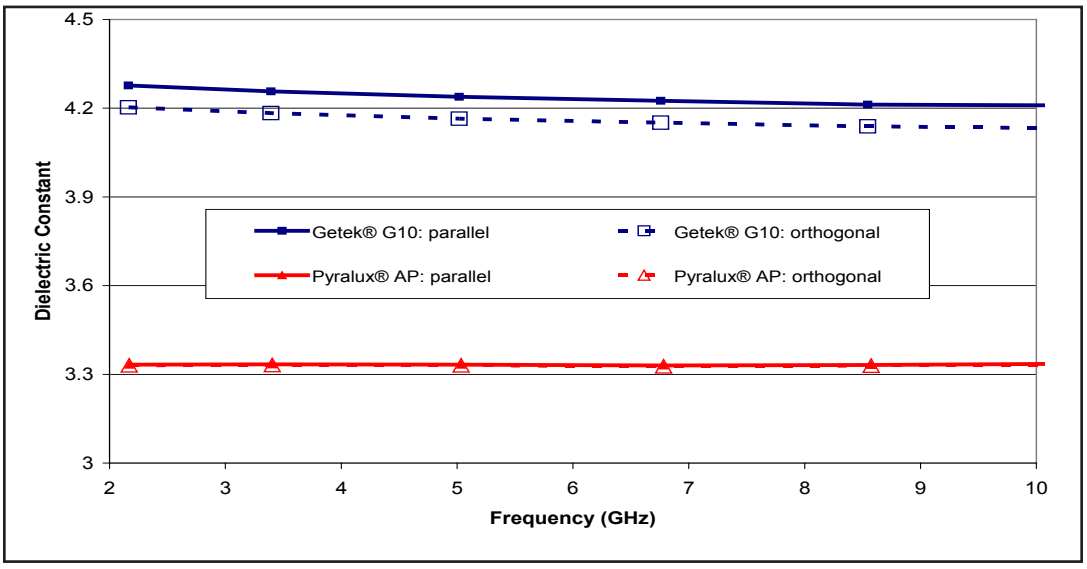


Figure 2: Antenna-Flex Circuit (250X). Large trace design and controlled impedance demands met using 10 mil thickness AP-*PLUS*.



Pyralux® AP-*PLUS* does not contain glass which gives it exceptional isotropy. The plot in Figure 3 demonstrates the consistency of dielectric constant over the entire material. Routed signals will see the same dielectric constant no matter which direction they are routed on the circuit board.

Figure 3: Dielectic Constant vs Frequency - Isotropy



The manufacturing process for Pyralux® AP-*PLUS* provides excellent thickness stability for applications where impedance must be closely controlled. Pyralux® AP-*PLUS* constructions provide average thickness tolerances of +/- 10% for all thickness choices (in contrast to other products at 15-20% thickness tolerance). This tight thickness control minimizes impedance variations of signal lines. In addition, having additional discrete thickness choices in Pyralux® AP-*PLUS* laminates enhances design flexibility.

Design Options to Maximize Circuit Yields and Signal Integrity in High-Frequency Circuits

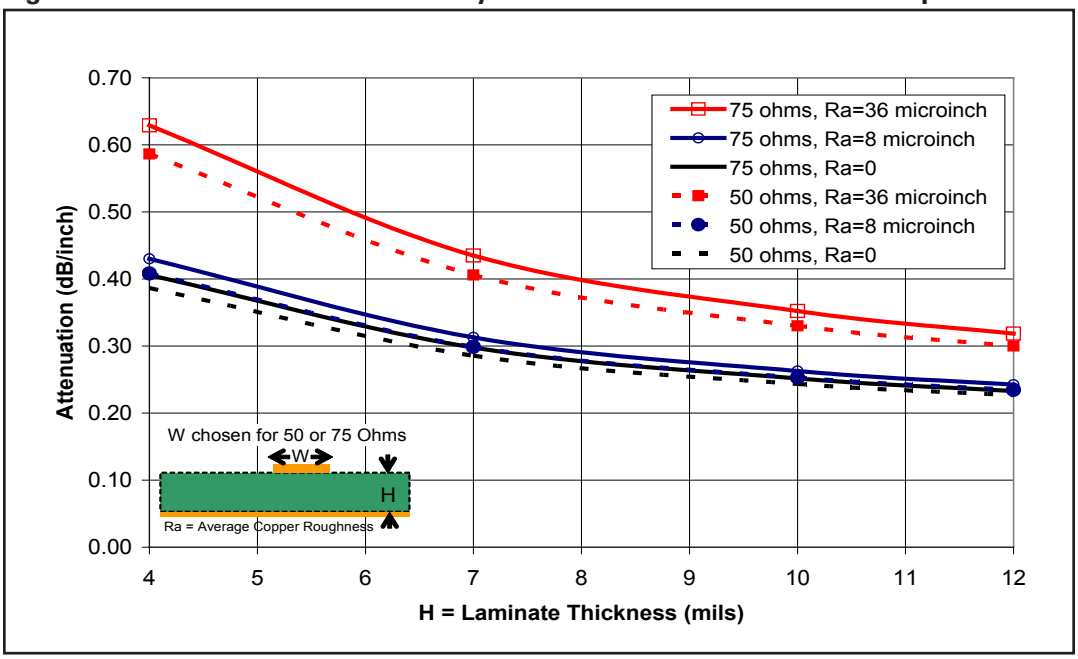
Low frequency applications do not require high precision tolerances to achieve the needed signal quality. However, for high-speed, high-frequency designs the substrate choice is critical to success. Pyralux® AP-*PLUS* all-polyimide thick copper-clad laminates offer designers a greater range of choices to help achieve the key design requirements for high-speed signal integrity, including:

- Minimized Noise, since three layer stripline circuits can be utilized instead of microstrip
- Impedance Control, due to tight thickness tolerance and isotropic all-polyimide material
- Minimized Attenuation, with low dielectric loss and low profile copper options available

Figure 4 below illustrates how attenuation is a significant concern at high frequencies. Attenuation can be reduced by using thicker Pyralux® AP-*PLUS* all-polyimide thick copper-clad laminates to create wider lines. Also, using low profile, smooth copper foil reduces attenuation by minimizing losses from the skin effect.

Pyralux® AP-*PLUS* is available in both standard and low-profile copper constructions.

Figure 4: Calculated Attenuation for Pyralux® AP *PLUS* 0.5 oz Cu Microstrip Lines at 10 GHz



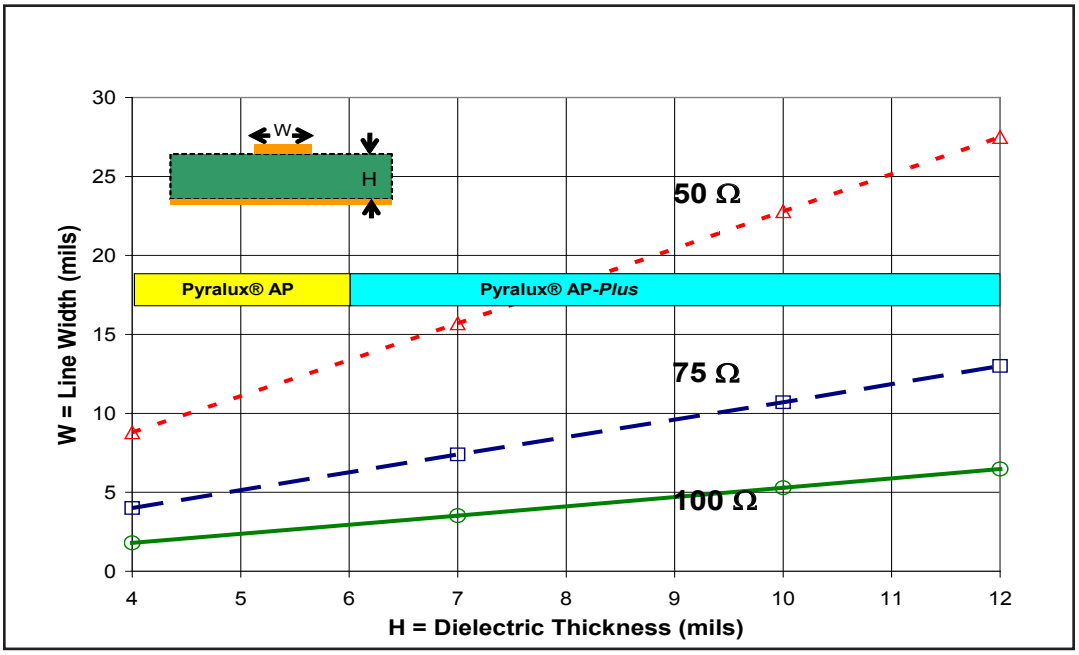
Controlled electrical impedance is required in a large portion of high performance circuit designs for current and next-generation applications. Packaging density, increasing clock frequencies, and interconnection demands have generated the need for differential impedance designs of 100 ohms and greater. To meet these requirements, a number of significant factors must be considered to achieve both the electrical demands and the inseparable practical aspects of fabricating a controlled impedance circuit with acceptable yields.

Electrical performance for increasing circuit density demands must be achieved through a balance of signal line spacing, signal-to-ground orientation, and dielectric material characteristics. Tolerance of the substrate thickness and overall package thickness have become significant variables in the successful design and fabrication of advanced interconnections. Pyralux® AP-*PLUS* laminates in 7-12 mil all-polyimide thicker base materials provide new design flexibility by allowing the use of greater line widths to achieve the desired impedance control while also providing fabricators with higher overall manufacturing yields in standard printed wiring board process equipment and chemistries.

Pyralux® AP-*PLUS* enables better manufacturing yields not only at 50 ohms, but at higher impedance values including 75 and 100 ohms. Designers and fabricators also have the flexibility of choosing thickness values in 1 mil increments to better optimize designs. As an example shown in Figure 5, a 75 ohm impedance design would require a 4 mil line/space fabrication using a 4 mil thick all-polyimide substrate. However, with an 8 mil thick Pyralux® AP-*PLUS* laminate, the same electrical output could be realized with 8-9 mil line/space traces which could offer a substantial manufacturing yield advantage.

Pyralux® AP-*PLUS* offers new design solutions in a range of standard thick-core laminate constructions.

Figure 5: Design Curve - 0.5 Oz Microstrip Using Pyralux® AP and AP-*PLUS*



Pyralux® AP-*PLUS*: Premium All-Polyimide Construction and Performance

Like standard DuPont™ Pyralux® AP all-polyimide thick copper-clad laminates, Pyralux® AP-*PLUS* all-polyimide thick copper-clad laminates are ideal for double sided, multilayer and rigid flex applications requiring advanced material performance and high reliability. All-polyimide constructions enable designers, fabricators, and assemblers to achieve demanding circuit applications through their core blend of superior chemical and mechanical characteristics:

- Low thermal expansion coefficient for rigid flex fabrication and assembly
- Excellent thermal resistance to high-temperature assembly
- Good dimensional stability consistency
- Superior mechanical and electrical properties
- good compatibility with severe environment applications (including aerospace and satellite).

All Pyralux® AP offerings are fully compatible with existing printed wiring board processes and material handling systems.

Typical Pyralux® AP-*PLUS* Material Properties

Table 3: 288°C (550°F) Solder Float Performance

Pyralux® AP Solder Float Resistance	Conditions	Results
Thermal Stress, Solder Shock	10 layer circuit similar to 50884C 100 mil centers, 288°C (550°F) 10-second dwell time	Pass No blisters, delamination, solder wicking
Test Method: IPC-TM-650, 2.4.13		

Chemical Resistance

Table 4: Chemical Absorption

Weight Change (%) 24 hr Immersion Pyralux® AP Pyralux® LF (polyimide) (acrylic)			Weight Change (%) 24 hr Immersion Pyralux® AP Pyralux® LF (polyimide) (acrylic)		
2 N Sulfuric Acid	0.95	3.44	KOH (1.5%, 55°C)	(9.42)	(51.85)
Isopropanol (IPA) Methyl Ethyl Ketone (MEK) Cupric Chloride Etchant	0.79 0.42 0.65	7.77 39.45 6.41	Permanganate Para-formaldehyde EDTA (E-less plating)	0.25 0.59 0.62	(46.50) 4.57 5.01

Pyralux® AP-*PLUS* Processing

Pyralux® AP-*PLUS* all-polyimide thick copper clad laminates handling and processing requirements are identical to standard 2 mil Pyralux® AP clads. They are fully compatible with all conventional flexible circuit fabrication processes including oxide treatment and wet chemical plated-through-hole desmearing. Fabricated circuits can be cover coated and laminated together to form multilayers or bonded to heat sinks using polyimide, acrylic, or epoxy adhesives.

General Information

Quality and Traceability

Pyralux® AP-*PLUS* copper clads are manufactured under a quality system registered to ISO9002. The clads are certified to IPC-4204/11. Complete material and manufacturing records, which include archive samples of finished product, are maintained by DuPont. Each manufactured lot is identified for reference and traceability. The packaging label serves as the primary tracking mechanism in the event of customer inquiry and includes the product name, batch number, size, and quantity.

Storage Conditions and Warranty

Pyralux® AP-*PLUS* does not require refrigeration and should be stored in the original packaging at temperatures of 4-29°C (40-85°F) and below 70% humidity. The product should not be frozen and should be kept dry, clean and well protected. Subject to compliance with the foregoing handling and storage recommendations, DuPont's warranties as provided in the DuPont Standard Conditions of Sale shall remain in effect for a period of two years following the date of shipment.

Safe Handling

Anyone handling Pyralux® AP-*PLUS* should wash their hands with soap before eating, smoking, or using restroom facilities. Although DuPont is not aware of anyone developing contact dermatitis when using Pyralux® AP-*PLUS* products, some individuals may be more sensitive than others. Gloves, finger cots, and finger pads should be changed daily. Pyralux® AP-*PLUS* is fully cured when delivered. However, lamination areas should be well ventilated with a fresh air supply to avoid build-up from trace quantities of residual solvent (typical of polyimides) that may volatilize during press lamination. When drilling or routing parts made with Pyralux® AP-*PLUS*, provide adequate vacuum around the drill to minimize worker exposure to generated dust. As with all thin, copper-clad laminates, sharp edges present a potential hazard during handling. All personnel involved in handling Pyralux® AP-*PLUS* clads should use suitable gloves to minimize potential cuts.

Packaging

Pyralux® AP-*PLUS* all-polyimide thick copper-clad laminates are supplied in the following standard sheet sizes:

24" x 36" (610mm x 914mm)
24" x 18" (610mm x 457mm)
24" x 12" (610mm x 305mm)
12" x 18" (305mm x 457mm)

Custom sizing up to 100" length (2.54 meters) is available through request to your DuPont representative, as are additional copper types and double-sided constructions. Specialty dielectric thickness constructions can also be requested.

Pyralux® AP *PLUS* packaging materials are 100% recyclable.

For more information on DuPont™ Pyralux® flexible circuit materials , please contact your local representative, or visit our website:

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