**DuPont™ Pyralux® APR**

**ALL-POLYIMIDE WITH EMBEDDED RESISTOR FOIL, FLEXIBLE LAMINATE**

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**Technical Data Sheet**

**Product Description**

DuPont™ Pyralux® APR double-sided, copper-clad resistor laminate is an all-polyimide composite of polyimide film bonded to copper foil, similar to Pyralux® AP, but including Ticer Technologies TCR® thin film copper resistor foil as one or both of the clad foils. This material system is ideal for multi-layer flex, rigid flex and rigid PCB applications which require reliable embedded resistor technology, advanced material performance, temperature resistance, high reliability, and robust processing. Offered in a wide range of dielectric thicknesses and resistance levels, Pyralux® APR provides designers, fabricators, and assemblers a versatile option for a wide variety of circuit constructions. Attributes include:

- Excellent resistive layer tolerance and electrical performance
- Excellent dielectric thickness tolerance
- Embedded capacitance and resistance in a single laminate
- Thin, rugged Cu-clad laminate with superior handling and processing
- High Cu-polyimide resistor foil adhesion strength
- Low CTE for flex and rigid multi-layer PCBs
- Excellent thermal resistance, up to 180°C (356°F) M.O.T.
- UL 94V-0, UL Registered, File E124294
- Compatible with PWB industry processes, IPC 4204/11 certified

**Packaging**

Pyralux® APR copper clad resistor laminate is supplied in the following standard sheet sizes:

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

Other sizes are available by special order. All Pyralux® APR packaging materials are 100% recyclable.

**Pyralux® APR Processing**

Pyralux® APR resistor foil copper clad handling and processing requirements are similar to standard 2 mil Pyralux® AP clads. Resistor formation requires a 2 or 3 step etch process, depending on the resistor material type selected (Table 2). Common etchant chemistries are used. Recommended processing information is available. The clads are typically compatible with conventional 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.

**Table 1: List of typical constructions**

<table>
<thead>
<tr>
<th>Product Code Examples</th>
<th>Resistivity (Ohms/square)</th>
<th>Dielectric Thickness (mil)</th>
<th>ED Copper Thickness (µm)</th>
<th>Resistor Thickness (oz/ft²)</th>
<th>Resistor Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>APR 02502535NC</td>
<td>025 = 25</td>
<td>025 = 1.0</td>
<td>135 µm</td>
<td>1.0 oz/ft²</td>
<td>NC = NiCr</td>
</tr>
<tr>
<td>APR 02502518NC</td>
<td>25</td>
<td>1.0</td>
<td>18 (0.5)</td>
<td>NC = NiCr</td>
<td></td>
</tr>
<tr>
<td>APR 02505035NC</td>
<td>25</td>
<td>2.0</td>
<td>35 (1.0)</td>
<td>NC = NiCr</td>
<td></td>
</tr>
<tr>
<td>APR 10002535NC</td>
<td>100</td>
<td>1.0</td>
<td>35 (1.0)</td>
<td>NC = NiCr</td>
<td></td>
</tr>
<tr>
<td>APR 10002518NC</td>
<td>100</td>
<td>1.0</td>
<td>18 (0.5)</td>
<td>NC = NiCr</td>
<td></td>
</tr>
<tr>
<td>APR 10005035NC</td>
<td>100</td>
<td>2.0</td>
<td>35 (1.0)</td>
<td>NC = NiCr</td>
<td></td>
</tr>
</tbody>
</table>

*Additional balanced/unbalanced copper constructions, dielectrics (>2 mil), and copper foils are available through your DuPont Representative.

Additional Ticer Technologies TCR® foil types are available (eg. 250 Ohm/square NiCrAlSi, etc.), one or both sides.

Ohms/square range includes 10, 25, 50, 100, 250.
Safe Handling
Anyone handling DuPont™ Pyralux® APR 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® APR products, some individuals may be more sensitive than others. Gloves, finger cots, and finger pads should be changed daily.

Pyralux® APR 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® APR, provide adequate vacuum around the drill to minimize worker exposure to generated dust.

Quality and Traceability
Pyralux® APR resistor foil copper clads are manufactured under a quality system registered to ISO9002 by Underwriters Laboratories. The clads are certified to IPC-4204/11. Material and manufacturing records, which include archived 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.

As with all thin, copper-clad laminates, sharp edges present a potential hazard during handling. All personnel involved in handling Pyralux® APR clads should use suitable gloves to minimize potential cuts.

Storage and Warranty
Pyralux® flexible laminates 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 for these products as provided in the DuPont Standard Conditions of Sale shall remain in effect for a period of one year following the date of shipment.

Pyralux® APR – Embedded Resistor and Foil Properties
Performance leading Ticer Technologies TCR® thin film resistor foil is combined with the unsurpassed reliability of all-polyimide Pyralux® AP construction to provide designers with unique options of embedded resistors in high performance flex or rigid PCB applications. Benefits include:

- Lighter and more rugged Rigid Flex and Rigid PCBs
- Optimized designs for minimal PCB X-Y-Z axis sizes
- Excellent resistor formation and smaller tighter lines
- Reliable resistor formation using common PCB chemistries and processes
- Small and predictable resistance shifts
- Thin dielectric also provides embedded planar capacitance capability
- High processing yields in thin laminate constructions
- Excellent high operating temperature and thermal resistance
- Excellent high voltage and power capability
- Reduced solder joints, rework, and PTH processing

Ticer Technologies TCR® foil Information (Data is courtesy of Ticer Technologies)

Figure A – Ticer Technologies TCR® Thin Film Resistor Foil

Figure B – Resistive alloy layer on copper made side
Figure C – Formed Embedded Resistor

![Formed Embedded Resistor Diagram](image)

### Table 2: Ticer Technologies TCR® Foil Properties

<table>
<thead>
<tr>
<th>Resistive Alloy</th>
<th>NiCr</th>
<th>NiCrAlSi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sheet Resistance (Ohms/sq.)</td>
<td>25, 50, 100</td>
<td>25, 50, 100, 250</td>
</tr>
<tr>
<td>Material Tolerance (%)</td>
<td>+/- 5</td>
<td>+/- 5</td>
</tr>
<tr>
<td>Temperature Coefficient of Resistance (max ppm/C)</td>
<td>110</td>
<td>-20</td>
</tr>
<tr>
<td>Base Copper Foil thickness (um)</td>
<td>18, 35</td>
<td>18, 35</td>
</tr>
<tr>
<td>Recommended Etch Solution</td>
<td>Cupric Chloride Ammoniacal N/A</td>
<td>Ammoniacal* Acidic Permanganate Ammoniacal* *Cupric Chloride alternatively</td>
</tr>
<tr>
<td>Resistor Tolerances (%)</td>
<td>Feature size 10 mil or greater Laser Trimmed</td>
<td>+/- 10 +/- 1.0</td>
</tr>
<tr>
<td>Minimum Feature Sizes*</td>
<td></td>
<td>5 mils Fabricator capability</td>
</tr>
<tr>
<td>“In trace” resistors Trace width Trace spacing Termination overlap Resistor “keep out”</td>
<td>Fabricator capability 2.5 mils 10 mils</td>
<td>5 mils Fabricator capability</td>
</tr>
<tr>
<td>* Power and resistance heating must also be considered.</td>
<td>2.5 mils 10 mils</td>
<td></td>
</tr>
<tr>
<td>Resistor Patterns</td>
<td>Fractional to high multiple squares. Serpentine and Others</td>
<td>Fractional to high multiple squares. Serpentine and Others</td>
</tr>
<tr>
<td>Maximum recommended power dissipation at 40°C (watts/sqin)</td>
<td></td>
<td>25 OPS: 250 50 OPS: 200 100 OPS: 150</td>
</tr>
<tr>
<td>OPS = ohm/sq.</td>
<td>250 OPS: 75</td>
<td></td>
</tr>
</tbody>
</table>

Note: Embedded resistors should be applied in rigid portions of PCBs and should not be placed in areas where dynamic flex will occur. Locating embedded resistors in flex-to-install locations is possible, but should be thoroughly tested and confirmed. Resistance values may be altered.
Figure D – Power Density by Resistor Type and Area

Figure E – Typical Resistance Shift after Embedded Lamination
(Average of 120 data points with different size embedded resistors, non-optimized.)

Properties common to both DuPont™ Pyralux® AP and APR Families

Table 3: Representative DuPont™ Pyralux® AP properties

<table>
<thead>
<tr>
<th>Laminate Property</th>
<th>AP-9111 1 mil dielectric</th>
<th>AP-9121 2 mil dielectric</th>
<th>AP-9131–9161 3–6 mil dielectric</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adhesion to Cu (Peel Strength) Method 2.4.9</td>
<td>1.6 (9)</td>
<td>&gt;1.8 (10)</td>
<td>&gt;1.8 (10)</td>
</tr>
<tr>
<td>As fabricated, N/mm (lb/in)</td>
<td>1.6 (9)</td>
<td>&gt;1.8 (10)</td>
<td>&gt;1.8 (10)</td>
</tr>
<tr>
<td>After solder, N/mm (lb/in)</td>
<td>Pass</td>
<td>Pass</td>
<td>Pass</td>
</tr>
<tr>
<td>Solder Float at 288°C (550°F) Method 2.4.13</td>
<td>Pass</td>
<td>Pass</td>
<td>Pass</td>
</tr>
<tr>
<td>Dimensional Stability Method 2.2.4</td>
<td>–0.04 to –0.08</td>
<td>–0.04 to –0.08</td>
<td>–0.03 to –0.06</td>
</tr>
<tr>
<td>Method B, %</td>
<td>–0.05 to –0.08</td>
<td>–0.04 to –0.07</td>
<td>–0.03 to –0.06</td>
</tr>
<tr>
<td>Dielectric Thickness Tolerance, % Method 4.6.2</td>
<td>±10</td>
<td>±10</td>
<td>±10</td>
</tr>
<tr>
<td>UL Flammability Rating ©UL-94</td>
<td>V-0</td>
<td>V-0</td>
<td>V-0</td>
</tr>
<tr>
<td>Dielectric Constant*, 1 MHz Method 2.5.5.3</td>
<td>3.4</td>
<td>3.4</td>
<td>3.4</td>
</tr>
<tr>
<td>Dissipation Factor*, 1 MHz Method 2.5.5.3</td>
<td>0.003</td>
<td>0.002</td>
<td>0.002</td>
</tr>
<tr>
<td>Dielectric Strength, kV/mil Method 2.3.4</td>
<td>7-9</td>
<td>6-7</td>
<td>6-7</td>
</tr>
<tr>
<td>Volume Resistivity, ohm-cm Method 2.5.17.1</td>
<td>E16</td>
<td>E17</td>
<td>E17</td>
</tr>
<tr>
<td>Surface Resistance, ohms Method 2.5.17.1</td>
<td>&gt;E16</td>
<td>&gt;E16</td>
<td>&gt;E16</td>
</tr>
<tr>
<td>Moisture &amp; Insulation Res., ohms Method 2.6.3.2</td>
<td>E11</td>
<td>E11</td>
<td>E11</td>
</tr>
<tr>
<td>Moisture Absorption, % Method 2.6.2</td>
<td>0.8</td>
<td>0.8</td>
<td>0.8</td>
</tr>
<tr>
<td>Tensile Strength, MPa (kpsi) Method 2.4.19</td>
<td>&gt;345 (&gt;50)</td>
<td>&gt;345 (&gt;50)</td>
<td>&gt;345 (&gt;50)</td>
</tr>
<tr>
<td>Elongation, % Method 2.4.19  &gt;50</td>
<td>&gt;50</td>
<td>&gt;50</td>
<td>&gt;50</td>
</tr>
<tr>
<td>Initiation Tear Strength, g Method 2.4.16</td>
<td>700–1000</td>
<td>900–1200</td>
<td>900–1200</td>
</tr>
<tr>
<td>Propagation Tear Strength, g Method 2.4.17.1</td>
<td>&gt;10</td>
<td>&gt;20</td>
<td>&gt;20</td>
</tr>
<tr>
<td>Chemical Resistance, min. % Method 2.3.2</td>
<td>Pass, &gt;95%</td>
<td>Pass, &gt;95%</td>
<td>Pass, &gt;95%</td>
</tr>
<tr>
<td>Solderability ©IPC-S-804, M. 1</td>
<td>Pass</td>
<td>Pass</td>
<td>Pass</td>
</tr>
<tr>
<td>Flexural Endurance, min. cycles Method 2.4.3</td>
<td>6000</td>
<td>6000</td>
<td>6000</td>
</tr>
<tr>
<td>Glass Transition (Tg), C —</td>
<td>220</td>
<td>220</td>
<td>220</td>
</tr>
<tr>
<td>Modulus, kpsi</td>
<td>700</td>
<td>700</td>
<td>700</td>
</tr>
<tr>
<td>In-Plane CTE (ppm/°C) T&lt;Tg —</td>
<td>25</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>In-Plane CTE (ppm/°C) T&gt;Tg —</td>
<td>40 (est.)</td>
<td>40 (est.)</td>
<td>40 (est.)</td>
</tr>
</tbody>
</table>
**Product Family Highlights and Data**

DuPont™ Pyralux® AP adhesiveless laminate was developed for high reliability flexible and rigid circuit applications requiring thin dielectric profiles and the superior performance provided by its all-polyimide construction. All-polyimide constructions enable designers, fabricators, and assemblers to achieve higher density, premium performance circuitry. The high material modulus provides excellent handling characteristics in a thin adhesiveless laminate. Pyralux® AP supports advanced circuit designs through its polyimide chemistry strengths:

- Thin adhesiveless polyimide core dielectric with excellent thickness uniformity for consistent electrical performance
- 12µm to 150µm (0.5-6.0mil) thick dielectric availability
- 12µm, 18µm, 24µm cores provide thin embedded planar capacitance
- 3mil-6 mil provide controlled impedance with high yield (Figure 8)
- Excellent adhesion of copper, resistor and dielectric
- Excellent long-term thermal exposure performance (Figure 1)
- Superior thermal resistance for high temperature applications and assembly processes
- UL 94V-0, UL Registered, File E124294
- Low thermal expansion coefficient is compatible with Cu and provides higher rigid-flex fabrication yields
- Consistent dimensional stability
- Superior mechanical and electrical properties
- Compatibility with severe environment applications
- Compatibility with most circuit processing and handling systems

![Pyralux® AP Solder Float Resistance](image)

**Table 4: 288°C (550°F) Solder Float Performance**

<table>
<thead>
<tr>
<th>Pyralux® AP Solder Float Resistance</th>
<th>Conditions</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal Stress, Solder Shock</td>
<td>10 layer circuit similar to 50884C 100 mil centers, 288°C (550°F) 10-second dwell time</td>
<td>Pass No blisters, delamination, solder wicking</td>
</tr>
</tbody>
</table>

Test Method: IPC-TM-650, 2.4.13
2 mil Pyralux® AP—Environmental Performance

Figure 3. Thermal Aging, 55°C (131°F)

Sample Construction, Pyralux® AP-9121

Average Peel Strength (P.L.)

0 6 12 18

Exposure Hours

0 100 250 500 1000

Note: Values represent average MD and TD results.

Figure 4. Thermal Cycling

Cycles: -55°C to 125°C

Average Peel Strength (P.L.)

0 6 12 18

Number of Cycles

0 100 250 500 1000

Note: Values represent average MD and TD results.

Figure 5. Temperature/Humidity Exposure

Continuous Test Environment: 85°C, 85% RH

Average Peel Strength (P.L.)

0 6 12

Exposure Hours

0 100 250 500 1000

Note: Values represent average MD and TD results.
Figure 6. Dielectric Constant vs. Frequency

Figure 7. Loss Tangent vs. Frequency

Notes: The Typical Adhesive Value is for the adhesive alone. When the Adhesive is used in conjunction with Kapton® H film for typical 3-layer copper clad, the Loss Tangent will be measurably lower—typically about 0.029.

Earlier data suggests that the Typical Adhesive value drifts up noticeably after 12 GHz.

The Pyralux® AP dielectric values are typical for constructions 1 through 6 mils of dielectric. A new 3-mil bondply made specifically for use with AP has equivalent Loss Tangent Values.
Figure 8 illustrates the fabrication benefits of thick DuPont™ Pyralux® AP core (vs. standard 2 mil) in a nominal 50 impedance microstrip circuit. Copper traces with 2x greater line/space resolution can be used to achieve identical electrical performance while greatly reducing fabrication yield loss from fine line imaging.

For more information on DuPont™ Pyralux® Flexible Circuit Materials, please contact your local representative, or visit our website for additional regional contacts:

**Americas**
DuPont Electronic Technologies  
14 T. W. Alexander Drive  
Research Triangle Park, NC 27709  
Tel: 800-243-2143

**Europe, Middle East & Africa**
DuPont de Nemours (Luxembourg) s.à r.l.  
Rue Général Patton, Contern  
L-2984 Luxembourg  
Tel: +352 3666 5935

**Japan**
DuPont KK  
Sanno Park Tower  
11-1, Nagata-cho 2-chome  
Chiyoda-ku, Tokyo 100-6111  
Tel: 81-3-5521-8660

**Taiwan**
DuPont Taiwan Hsinchu Branch.  
#2, Li-Hsin 4th Rd., Hsinchu Science Park, Hsinchu 30078, Taiwan  
Tel: 886-3-5799364

**India**
E.I.DuPont India Limited  
1001-1012 “Meadows”, 10th Floor  
Sahar Plaza Complex  
Andheri-Kurla Road, Andheri (East)  
Mumbai 400 059, India  
Tel: 91-22-6751-5000  
DID: 91-22-6751-5038  
Fax : 91-22-67101937

**China**
DuPont China Holding Co., Ltd. Shanghai Branch  
Bldg. 11, 399 Keyuan Road  
Zhangjiang Hi-Tech Park  
Pudong New District  
Shanghai 201203, China  
Tel: 86-21-38622720

**Korea**
DuPont Korea Inc.  
4/5 Floor, Asia Tower  
#726, Yeoksam-dong, Kangnam-ku, Seoul  
135-082 Korea  
Tel: 82-2-2222-5224

**Singapore**
DuPont Singapore Pte, Ltd.  
1 HarbourFront Place #11-01  
HarbourFront Tower One  
Singapore 098633  
Tel: 65-6586-3091

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