Substrates

♦ Rigid laminate
♦ Metal core
♦ Flexible films
♦ Ceramic
Substrate

- Provides electrical interconnect and isolation
- Mounting surface for components
  - Must be compatible with assembly processes
Laminate Substrate

♦ Dielectric
  – Polymer
    • Epoxy
    • Polyimide
    • Cyanate Ester
  – Reinforcement
    • Glass fabric
    • Kevlar
    • Paper

♦ Conductor
  – Copper
Basic Material Property Considerations

♦ Glass transition Temperature, $T_g$
  - Hard, brittle, glassy $\rightarrow$ soft, rubbery

![Graph showing force versus deformation with curves for glassy and rubbery states](graph.png)
$T_g$

- Above $T_g$ the modulus (slope of Force vs. Deformation) decreases
Above the $T_g$ the coefficient of expansion decreases
CTE – Laminate Substrates

♦ CTE of polymers typically 50-80ppm/°C
♦ Reinforcement materials are used to control the CTE in the X-Y plane
  – Woven glass fabrics
  – Kevlar
  – Etc.
♦ CTE in X-Y plane typically 14-18ppm/°C to match CTE of Copper (16ppm/°C)
♦ CTE in Z-direction 100-200ppm/°C
Laminate PWB Construction
Effect of Temperature During Soldering

Room temperature - no strain

During Soldering
CTE

- Epoxy: 50-80 ppm/°C
- Glass reinforcement: 0.5 ppm/°C
- PWB Dielectric: 14-20 ppm/°C
- Copper: 16 ppm/°C
- Components: 6-20 ppm/°C
CTE Effect on Components

Ceramic chip carrier with low CTE

Substrate with high CTE

Stressed soldered joints
# Characteristics of Substrate Options

<table>
<thead>
<tr>
<th>TYPE</th>
<th>MAJOR ADVANTAGES</th>
<th>MAJOR DISADVANTAGES</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic based substrates</td>
<td>Substrate size; weight; reworkable; dielectric properties; conventional board processing</td>
<td>Thermal conductivity; X, Y, and Z axis CTE</td>
<td>Because of its high X-Y plane CTE, it should be limited to environments and applications with small changes in temperature and/or small packages</td>
</tr>
<tr>
<td>Polyimide fiberglass</td>
<td>Same as epoxy fiberglass plus high temperature Z axis CTE; substrate size; weight; reworkable; dielectric properties</td>
<td>Thermal conductivity; X and Y axis CTE; moisture absorption; brittle resin (prone to cracking); very poor adhesive—low bond strength to copper; Cost 2X–5X of FR-4</td>
<td>Same as epoxy fiberglass</td>
</tr>
<tr>
<td>Epoxy aramid fiber woven</td>
<td>Same as epoxy fiberglass; X-Y axis CTE; substrate size; lightweight; reworkable; dielectric properties</td>
<td>Thermal conductivity; X and Y axis CTE; resin microcracking; Z axis CTE; water absorption; cost 3X to 5X FR-4</td>
<td>Volume fraction of fiber can be controlled to tailor X-Y CTE. Resin selection critical to reducing resin microcracks.</td>
</tr>
<tr>
<td>108 and 120 cloth</td>
<td>Same as epoxy aramid fiber but eliminates resin cracking; thin multilayer board; decreased Z axis CTE</td>
<td>Low strength; Cost 2X–3X of FR-4</td>
<td>Used in conjunction with lightweight, low CTE metal substrate</td>
</tr>
<tr>
<td>Epoxy aramid paper</td>
<td>Same as epoxy aramid fiber but eliminates resin cracking; thin multilayer board; decreased Z axis CTE</td>
<td>Low strength; Cost 2X–3X of FR-4</td>
<td>Used in conjunction with lightweight, low CTE metal substrate</td>
</tr>
</tbody>
</table>
### Characteristics of Substrate Options

<table>
<thead>
<tr>
<th>Material</th>
<th>Properties</th>
<th>Thermal and Size Considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polyimide aramid fiber</td>
<td>Same as epoxy aramid fiber; Z axis CTE; substrate size; weight; reworkable; dielectric properties</td>
<td>Thermal conductivity; X and Y axis CTE; resin microcracking; water absorption. Same as epoxy aramid fiber.</td>
</tr>
<tr>
<td>Polyimide quartz (fused silica)</td>
<td>Same as polyimide aramid fiber; Z axis CTE; substrate size; weight; reworkable; dielectric properties</td>
<td>Thermal conductivity; X and Y axis CTE; Z axis CTE; drilling; availability; cost; low resin content required. Volume fraction of fiber can be controlled to tailor X-Y CTE. Drill wearout higher than with fiberglass.</td>
</tr>
<tr>
<td>Fiberglass/aramid composite fiber</td>
<td>Same as polyimide aramid fiber; no surface microcracks; Z axis CTE; substrate size; weight; reworkable; dielectric properties</td>
<td>Thermal conductivity; X and Y axis CTE; water absorption; process solution entrapment. Resin microcracks are confined to internal layers and cannot damage external circuitry.</td>
</tr>
<tr>
<td>Fiberglass/Teflon laminates</td>
<td>Dielectric constant; high temperature</td>
<td>Same as epoxy fiberglass; low temperature stability; thermal conductivity; X and Y axis CTE. Suitable for high speed logic applications. Same as epoxy fiberglass.</td>
</tr>
<tr>
<td>Flexible dielectric</td>
<td>Lightweight; minimal concern to CTE; configuration flexibility</td>
<td>Size</td>
</tr>
</tbody>
</table>
Characteristics of Substrate Options

<table>
<thead>
<tr>
<th>TYPE</th>
<th>MAJOR ADVANTAGES</th>
<th>MAJOR DISADVANTAGES</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermoplastic</td>
<td>3-D configurations; low high-volume cost</td>
<td>High injection molding setup costs</td>
<td>Relatively new for these applications.</td>
</tr>
<tr>
<td>NONORGANIC BASE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alumina (ceramic)</td>
<td>CTE; thermal conductivity; conventional thick film or thin film processing; integrated resistors</td>
<td>Substrate size; rework limitations; weight; cost; brittle; dielectric constant</td>
<td>Most widely used for hybrid circuit technology.</td>
</tr>
<tr>
<td>SUPPORTING PLANE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Printed board bonded to plane support (metal or nonmetal)</td>
<td>Substrate size; reworkability; dielectric properties; conventional board processing; X-Y axis CTE; stiffness; shielding; cooling</td>
<td>Weight</td>
<td>The thickness/CTE of the metal core can be varied along with the board thickness, to tailor the overall CTE of the composite.</td>
</tr>
<tr>
<td>Sequential processed board with supporting plane core</td>
<td>Same as board bonded to supporting plane</td>
<td>Weight</td>
<td>Same as board bonded to supporting plane.</td>
</tr>
</tbody>
</table>
## Characteristics of Substrate Options

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discrete wire</td>
<td>High speed interconnections; good thermal and electrical features</td>
</tr>
<tr>
<td><strong>CONSTRAINING CORE</strong></td>
<td></td>
</tr>
<tr>
<td>Porcelainized copper clad invar</td>
<td>Same as Alumina</td>
</tr>
<tr>
<td>Printed board bonded with</td>
<td>Same as board bonded to supporting plane</td>
</tr>
<tr>
<td>constraining metal core</td>
<td></td>
</tr>
<tr>
<td>Printed board bonded to low</td>
<td>Same as board bonded to low expansion metal cores; stiffness, thermal</td>
</tr>
<tr>
<td>expansion graphite fiber core</td>
<td>conductivity; low weight</td>
</tr>
<tr>
<td>Compliant layer structures</td>
<td>Substrate size; dielectric properties; X-Y axis, CTE</td>
</tr>
</tbody>
</table>
Ceramic Substrates

- Thick Film
- Low Temperature Cofired Ceramic (LTCC)
- High Temperature Cofired Ceramic (HTCC)
Thermal Conductivity

![Graph showing thermal conductivity of different materials vs. temperature.]
Thermal Conductivity

![Graph showing thermal conductivity vs. temperature for various materials.](image)
Thick Film Processing

- Sequential printing and firing of:
  - Conductor
  - Dielectric
  - Resistor

layers onto a base ceramic substrate
Thick Film Screen Printing Process

Squeegee → Ink → Wire Mesh → Frame → Emulsion → Substrate
Conductor Print
Cofired Technology

♦ Cofired Ceramic
  – Firing Temperature: 1500 - 1600°C

♦ Glass/Ceramic
  – Firing Temperature: 850 - 1050°C
Cofired Process

- Top Conductor Layer
- Via
- Second Layer Conductor
- Thin Tape
- Thick Tape
Glass/Ceramic

♦ Conductors
  – Au, Ag, PdAg, Cu

♦ Dielectrics
  – Crystallizable Glasses
    • Cordierite MgO-SiO$_2$-Al$_2$O$_3$
  – Glass Filled Composites
    • SiO$_2$-B$_2$O$_3$ type glass + Al$_2$O$_3$
    • PbO- SiO$_2$-B$_2$O$_3$ - CaO type glass + Al$_2$O$_3$
  – Crystalline Phase Ceramics
    • Al$_2$O$_3$ - CaO - SiO$_2$, MgO - B$_2$O$_3$
    • BaSn(BO$_3$)$_2$
Cofired Ceramic

♦ Conductor
  – Tungsten
  – Molybdenum/Manganese

♦ Dielectric
  – 88 - 92% Al₂O₃
**Typical Cofired Properties**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Co-fired Ceramic</td>
<td></td>
</tr>
<tr>
<td>Co-fired Glass/Ceramic</td>
<td></td>
</tr>
<tr>
<td>CTE</td>
<td>6.5 ppm/°C</td>
</tr>
<tr>
<td>Thermal Conductivity</td>
<td>15-20W/m°C</td>
</tr>
<tr>
<td>Camber</td>
<td>1-4 mils/in.</td>
</tr>
<tr>
<td>Surface Roughness</td>
<td>10-20µµµ µµµ µµµ µµµ</td>
</tr>
<tr>
<td>Flexural Strength</td>
<td>275-400 MPa</td>
</tr>
<tr>
<td></td>
<td>15-250 MPA</td>
</tr>
</tbody>
</table>
## Typical Properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Value 1</th>
<th>Value 2</th>
<th>Value 3</th>
<th>Value 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cofired Al₂O₃</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cofired Glass/Ceramic</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Line width (min.)</td>
<td>100 µm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Via Dia. (min.)</td>
<td>125 µm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of Layers</td>
<td>1 - 100</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conductor Resistance</td>
<td>8 – 12 Ω/sq.</td>
<td>3 – 20 Ω/sq.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dielectric Constant</td>
<td>9 - 10</td>
<td>5 – 8 @ 1MHz</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Typical Properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cofired</strong></td>
<td></td>
</tr>
<tr>
<td>Al$_2$O$_3$</td>
<td></td>
</tr>
<tr>
<td><strong>Dissipation Factor</strong></td>
<td>5 – 15 x 10$^{-4}$</td>
</tr>
<tr>
<td></td>
<td>@1MHz</td>
</tr>
<tr>
<td><strong>Insulation Resistance</strong></td>
<td>&gt; 10$^{14}$ Ω·cm</td>
</tr>
<tr>
<td></td>
<td>– 10$^{12}$ - 10$^{15}$ Ω·cm</td>
</tr>
<tr>
<td><strong>Breakdown Voltage</strong></td>
<td>550V/25 µm</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Resistor Values</strong></td>
<td>0.1 – 1MΩ</td>
</tr>
</tbody>
</table>
Cofired Glass/Ceramic
Constrained Core Substrates

- Copper/Invar/Copper (Invar – Ni/Fe)
- Alloy 42
- SiC-Al composite
- Graphite
Compliant Layers
# Selection Criteria

<table>
<thead>
<tr>
<th>DESIGN PARAMETERS</th>
<th>TRANSITION TEMPERATURE</th>
<th>COEFFICIENT OF THERMAL EXPANSION</th>
<th>THERMAL CONDUCTIVITY</th>
<th>TENSILE MODULUS</th>
<th>FLEXURAL MODULUS</th>
<th>DIELECTRIC CONSTANT</th>
<th>VOLUME RESISTIVITY</th>
<th>SURFACE RESISTIVITY</th>
<th>MOISTURE ABSORPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature &amp; Power Cycling</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
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<tr>
<td>Vibration</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mechanical Shock</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperature &amp; Humidity</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Power Density</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chip Carrier Size</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Circuit Density</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Circuit Speed</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>
# Substrate Properties

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>UNIT OF MEASURE</th>
<th>GLASS TRANSITION TEMPERATURE (°C)</th>
<th>XY COEFFICIENT OF THERMAL EXPANSION (PPM/°C) (note 2)</th>
<th>THERMAL CONDUCTIVITY (W/M·°C)</th>
<th>XY TENSILE MODULUS (PSI × 10⁻⁹)</th>
<th>DIELECTRIC CONSTANT (At 1 MHz)</th>
<th>VOLUME RESISTIVITY (Ohms/cm)</th>
<th>SURFACE RESISTIVITY (Ohms)</th>
<th>MOISTURE ABSORPTION (Percent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Epoxy Fiberglass</td>
<td></td>
<td>125</td>
<td>13–18</td>
<td>0.16</td>
<td>2.5</td>
<td>4.8</td>
<td>10¹²</td>
<td>10¹³</td>
<td>0.10</td>
</tr>
<tr>
<td>Polyimide Fiberglass</td>
<td></td>
<td>250</td>
<td>12–16</td>
<td>0.16</td>
<td>2.8</td>
<td>4.8</td>
<td>10¹⁴</td>
<td>10¹³</td>
<td>0.35</td>
</tr>
<tr>
<td>Epoxy Aramid Fiber</td>
<td></td>
<td>125</td>
<td>6–8</td>
<td>0.12</td>
<td>4.4</td>
<td>3.9</td>
<td>10¹⁶</td>
<td>10¹⁶</td>
<td>0.85</td>
</tr>
<tr>
<td>Polyimide Aramid Fiber</td>
<td></td>
<td>250</td>
<td>3–7</td>
<td>0.15</td>
<td>4.0</td>
<td>3.6</td>
<td>10¹²</td>
<td>10¹²</td>
<td>1.50</td>
</tr>
<tr>
<td>Polyimide Quartz</td>
<td></td>
<td>250</td>
<td>6–8</td>
<td>0.30</td>
<td>4.0</td>
<td>4.0</td>
<td>10¹⁰</td>
<td>10¹¹</td>
<td>0.50</td>
</tr>
<tr>
<td>Fiberglass/Teflon</td>
<td></td>
<td>75</td>
<td>20</td>
<td>0.26</td>
<td>0.2</td>
<td>2.3</td>
<td>10¹⁰</td>
<td>10¹¹</td>
<td>1.10</td>
</tr>
<tr>
<td>Thermoplastic Resin</td>
<td></td>
<td>190</td>
<td>25–30</td>
<td>3–4</td>
<td>3–4</td>
<td>10³⁷</td>
<td>10¹³</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Alumina-Beryllia</td>
<td>NA</td>
<td>5–7</td>
<td>21.0</td>
<td>44.0</td>
<td>8.0</td>
<td>10¹⁴</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Aluminum (6061 T-6)</td>
<td>NA</td>
<td>23.6</td>
<td>200</td>
<td>10</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>
### Substrate Properties

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>GLASS TRANSITION TEMPERATURE</th>
<th>XY COEFFICIENT OF THERMAL EXPANSION</th>
<th>THERMAL CONDUCTIVITY</th>
<th>XY TENSILE MODULUS</th>
<th>DIELECTRIC CONSTANT</th>
<th>VOLUME RESISTIVITY</th>
<th>SURFACE RESISTIVITY</th>
<th>MOISTURE ABSORPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper (CDA101)</td>
<td>NA</td>
<td>17.3</td>
<td>400</td>
<td>17</td>
<td>NA</td>
<td>10&lt;sup&gt;6&lt;/sup&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Copper-Clad Invar</td>
<td>NA</td>
<td>3–6</td>
<td>150XY/20Z</td>
<td>17–22</td>
<td>NA</td>
<td>10&lt;sup&gt;6&lt;/sup&gt;</td>
<td></td>
<td>NA</td>
</tr>
</tbody>
</table>

**Notes:**
1. The X and Y expansion is controlled by the core material and only the Z axis is free to expand unrestrained. Where the Tg will be the same as the resin system used.
2. Figures are below glass transition temperature, are dependent on method of measurement and percentage of resin content.
NA—Not applicable.
# Laminate Materials

<table>
<thead>
<tr>
<th>Common Designation</th>
<th>Resin System</th>
<th>Base Material</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>XXXP</td>
<td>Phenolic</td>
<td>Paper</td>
<td>Punchable @ R.T.</td>
</tr>
<tr>
<td>XXXPC</td>
<td>Phenolic</td>
<td>Paper</td>
<td>Punchable @ or above R.T. XXXP &amp; XXXPC are widely used in high volume single sided consumer applications</td>
</tr>
<tr>
<td>G-10</td>
<td>Epoxy</td>
<td>Glass fibers</td>
<td>General purpose material system</td>
</tr>
<tr>
<td>G-11</td>
<td>Epoxy</td>
<td>Glass fibers</td>
<td>Same as G-10, but can be used to higher temperatures</td>
</tr>
</tbody>
</table>
# Laminate Materials

<table>
<thead>
<tr>
<th>Common Designation</th>
<th>Resin System</th>
<th>Base Material</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>FR-2</td>
<td>Epoxy</td>
<td>Paper</td>
<td>Same as XXXPC, but has a flame retardant (FR) system that renders it self-extinguishing</td>
</tr>
<tr>
<td>FR-3</td>
<td>Epoxy</td>
<td>Paper</td>
<td>Punchable @ R.T. and has flame retardant</td>
</tr>
<tr>
<td>FR-4</td>
<td>Epoxy</td>
<td>Glass fibers</td>
<td>Same as G-10, but has flame retardant</td>
</tr>
<tr>
<td>FR-5</td>
<td>Epoxy</td>
<td>Glass fibers</td>
<td>Same as FR-4, but has better strength and electrical properties @ higher temperatures</td>
</tr>
</tbody>
</table>
# Laminate Materials

<table>
<thead>
<tr>
<th>Common Designation</th>
<th>Resin System</th>
<th>Base Material</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>FR-6</td>
<td>Polyester</td>
<td>Glass fibers</td>
<td>Designed for low capacitance or high impact resistance; has flame retardant</td>
</tr>
<tr>
<td>Polyimide</td>
<td>Polyimide</td>
<td>Glass fibers</td>
<td>Better strength &amp; demonstrated stability to a higher temperature than FR-4</td>
</tr>
<tr>
<td>GT or GX</td>
<td>Teflon</td>
<td>Glass fibers</td>
<td>Controlled dielectric laminate. GX has better tolerance of dielectric properties than GT</td>
</tr>
</tbody>
</table>
## Highest Continuous Operating Temperatures (°C)

<table>
<thead>
<tr>
<th>Material</th>
<th>Electrical</th>
<th>Mechanical</th>
</tr>
</thead>
<tbody>
<tr>
<td>XXXP</td>
<td>125</td>
<td>125</td>
</tr>
<tr>
<td>XXXPC</td>
<td>125</td>
<td>125</td>
</tr>
<tr>
<td>G-10</td>
<td>130</td>
<td>130</td>
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PWB Fabrication
PWB Fabrication

- Starting Material: Cu clad Core

Cu

Epoxy Glass Core
PWB Fabrication: Interlayer Processing

- Shear
- Mark Mat.
- Bake
- Drill Reg. Holes
- Clean
- Strip Resist
- Etch
- Develop
- Photo Print
- Dry Film Lamiantion
- Inspect
- Test
- Clean
- Oxide Treatment
- Bake
PWB Fabrication:
Apply Dry Film Photoresist
PWB Fabrication: Expose Photoresist

UV Light
PWB Fabrication: Develop Photoresist
PWB Fabrication:
Etch Copper – 
$\text{CuCl}_2/\text{HCl}$, 2:1
PWB Fabrication: Strip Photoresist
PWB Fabrication: Black Oxide Treatment
PWB Fabrication: Multilayer Processing

- Shear ‘B’ Stage Prepreg
- Lay-up
- Lamination
- Trim Flash
- Remove Fixture
- Cool down
PWB Fabrication: Lamination

1 oz. Cu
Prepreg
Prepreg
Inner Layer
Prepreg
1 oz. Cu
Release Paper
Bottom Lam. Fixture
Tooling Holes
Top Lamination Fixture
Release Paper
PWB Fabrication: Multilayer Processing

Mark ID → Bake → Drill Plated Through Holes

Hole Clean: De-smear → Deburr
PWB Fabrication: Drill & De-smear
PWB Fabrication: Multilayer Processing

- Pd Seed
- Electroless Cu Plate
- Clean
- Photoresist Application

- Electroplate Sn/Pb
- Electroplate Cu
- Develop
- Photo Print

- Strip Resist
- Etch
- Strip Sn/Pb
PWB Fabrication:
Pd Seed & Electroless Cu Plate
PWB Fabrication: Photo Resist Application, Exposure & Develop
PWB Fabrication: Electroplate Cu
Copper Thickness

Room temperature - no strain

During Soldering
Barrel Cracking
Barrel Cracking
PWB Fabrication:
Electroplate Sn/Pb
PWB Fabrication:
Strip Photoresist & Etch Cu
PWB Fabrication:
Strip Sn/Pb
PWB Fabrication: Multilayer Processing

- Soldermask Application & Cure
- Route & Bevel
- Final Electrical & Mechanical Test
- Legend Print & Cure
- Drill Non-Plated Holes
- Hot Air Solder Level
- Clean
- Final Electrical & Mechanical Test
PWB Fabrication:
Solder Mask Application
Solder Masks

Types of Soldermask

- Temporary
  - Washable
  - Peelable
    - Aqueous
    - Solvent
- Permanent
Solder Mask

- Permanent
  - Dry Film
    - Aqueous
    - Solvent
  - Wet Screened
    - Photo imageable
      - Curtain Coat
      - Screened
    - Wet Screen
      - UV Cure
      - Thermal Cure
Hole Tenting with Dry Film
PWB Fabrication:
Hot Air Solder Level
Hot Air Leveled Process (HASL)

- Solder dip and hot air solder leveling is a common PCB surface finish for solder attachment.
  - Sn/Pb coating is applied after the solder mask application, coating only the contact areas, plated holes and contact pads
  - Coated boards are cleaned, fluxed and dipped into molten solder.
  - While the alloy is still in the liquid state, excess material is blown off the contact surface with hot air, leaving a solder coated surface finish.
Issues related to HASL

♦ Uneven surface plating
♦ Crowning of solder on fine pitch and CSP sites
♦ Solder paste uniformity
♦ Tin/Copper intermetallic migration
♦ Extreme Thermal shock
  – Board warp
  – Delamination
  – Damage to the plated holes
  – Defects that may effect long term reliability.
Ni/Au Electroless Process

- Electroless Ni is applied over the exposed bare copper after solder mask coating process.
  - The fabricator will typically use the Sn/Pb plated circuit pattern as an etch resist and strip the Sn/Pb after etching.
  - Exposed attachment sites and holes are plated with the Ni using electroless plating process followed by a layer of gold by immersion process as well.
  - Typical
    - Electroless Ni thickness : 125 - 200 μ in
    - Immersion Gold thickness : 3 - 8 μ in
    - Ni improves plated through hole reliability
Ni/Au Electroplating Process

♦ Electroplated Ni/Au is applied after hole plating.
♦ Ni/Au is resistant to the acid used to etch away copper.
  – This replaces the plating and subsequent stripping of Sn/Pb.
♦ This method can furnish finer lines and spaces.
♦ Typical
  – Electroplated Ni thickness : 100 - 150 µ in
  – Electroplated AU thickness : 3 - 5 µ in
A word of caution…

- The gold plating volume within the solder joint should be less than 3% and preferably less than 1% to avoid embrittlement of the joint and intermetallic formation.
  - Gold thickness will depend on solder volume

- Current industry issue with Electroless Ni/Immersion Au.
  - Low occurrence rate of failures in mechanical shock related to the immersion gold process
Solder Ball with Crack at Pad Interface

Courtesy:
Bruce Houghton
Celestica
Black Pad

Courtesy:
Bruce Houghton
Celestica
Electroless Ni/Immersion Au

- Root cause (current theory): nickel is attacked or excessively corroded in the gold bath.
  - Somewhat design dependent
  - Somewhat chemistry dependent
  - Not related to phosphorous content in Ni

Pd or Ni/Pd (electroless) Plating

- Pd coatings have been developed as an alternative to solder and Ni/Au.
- Process is relatively new, but proven to be compatible with solder attachment processes.
- Pd is applied to the exposed circuit features using electroless plating method and is compatible with either Ni alloy as a base plating or the bare Cu alloy surface.
- Low cost, low stress process
- Pd metal cost is high
Immersion Ag

- Provides a solderable coating
- Ag dissolves into molten solder
- Growing in popularity
Immersion or White Tin

♦ Good initial solderability
♦ Sn-Cu intermetallic formation and oxidation limit use with multiple soldering cycles
Alternatives to Alloy Plating

♦ As an alternative to plating, many companies have had success and economic advantage as well as a flat attachment surface with organic preservatives or pre-flux coatings over bare copper.

♦ As a means of retarding oxide growth on the bare copper attachment sites and via/test pads, a preservative or inhibitor coating is applied to the board. Organic/Nitrogen coatings such as, Benzotriazole or Imidazole are used instead of alloy finishes.
Advantages of OSP

♦ Multiple exposure capability
♦ Ease of visual inspection of deteriorated copper (if any)
♦ Excellent pad coplanarity
♦ Consistent solderability
Concerns of OSP Coated Boards

♦ Degrades in high humidity/temperature
♦ Limited (6-12 months) shelf life
♦ Physical contact can degrade coating
♦ Exposed copper will (in time) tarnish