Continuing..

**PRINTED WIRING BOARD TECHNOLOGIES**
Manufacture of RIGID Laminate

Formulate resin mix + solvents
Select glass cloth (filler)
Coat glass cloth with resin
Remove solvents by drying
Lay copper foil on “prepreg” sheet
Press together at 400-700 psi pressure and 180 C
Slowly cool and cut to size

Fig. source: unknown
Laminates Qualification

IPC: Institute of Interconnecting and Packaging of Electronic Circuits
DoD: Department of Defense for Military Standard Specifications [MIL]
NEMA: National Engineering Manufacturers Association
UL: Underwriters Laboratory

IPC Laminate Specifications
- IPC-L-108A/B Thin Laminates
- IPC-L-109A/B Glass cloth for laminates
- IPC-L-115A/B Rigid Laminates
- IPC-L-125 Laminates for high frequency

MIL- Laminate Specifications
MIL - S - 13949

NEMA Laminate Specifications
NEMA- L1- 1- 1989
NEMA Grades

- FR-1 Phenolic-heavy paper base
- FR-2 Phenolic-low paper base
- FR-3 Phenolic-paper base/flame retardant
- FR-4 Epoxy-glass base/flame retardant
- FR-5 Epoxy-glass base
- FR-6 Polyester-glass base
- CEM-1 Epoxy-woven glass + paper
- CEM-2 Polyester-woven glass + paper
- CEM-3 Epoxy-non-woven glass + paper
- CEM-4 Polyester-non-woven glass + paper

MIL Grades

- GB Poly-functional Epoxy-woven glass
- GC Cyanate ester-woven glass
- GE Epoxy-woven glass
- GF Difunctional Epoxy-woven glass-flame retardant
- GH Polyfunctional Epoxy-woven glass-high temp
- GI Polyimide-woven glass
- QI Polyimide-woven quartz
- GR
- GP Teflon-non woven glass
- GT
- GX
- GY Teflon-woven glass

Composite epoxy material: CEM
Rigid Laminates

- Core Laminate thicknesses:
  - 0.8mm; 1.6mm; 3.2mm
- Copper thicknesses:
  - 8micron; 18um; 35um

<table>
<thead>
<tr>
<th>Type</th>
<th>Weight [g/m²]</th>
<th>Thickness [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>106</td>
<td>25</td>
<td>0.050</td>
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<tr>
<td>1080</td>
<td>49</td>
<td>0.065</td>
</tr>
<tr>
<td>2112</td>
<td>70</td>
<td>0.090</td>
</tr>
<tr>
<td>2113</td>
<td>83</td>
<td>0.100</td>
</tr>
<tr>
<td>2125</td>
<td>88</td>
<td>0.100</td>
</tr>
<tr>
<td>2116</td>
<td>108</td>
<td>0.115</td>
</tr>
<tr>
<td>7628</td>
<td>200</td>
<td>0.190</td>
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</tbody>
</table>

- Different grades of prepreg:
  - e.g. 7628 (200g/sqm) is 0.19mm thick
  - 8 layers of such are used for a 1.6mm FR4 type laminate
  - Another e.g. 2125 (88gms) is 0.10mm thick

So, how is FR4 substrate dielectric prepared?
FR4 is a glass fiber epoxy laminate. It is the most commonly used PCB material. 0.8mm FR4 grade uses 4 layers of (7628) glass fiber material.

Isn't FR4 green in color?
No, it is usually transparent. The green color comes from the solder mask in the PCB finished product.
Laminate Properties

Physical, Thermal, Electrical and Environmental requirements

Physical

1. Laminate integrity
   - Laminate thickness
   - Resin starvation
   - Voids
   - Foreign inclusion

2. Bow and Twist
   - Very important as it induces strain on Solder Joints
   - Flat
   - No warpage

3. Flexural Strength
   - Ability not to FLEX under mechanical load

4. Peel Strength
   - As received After Solder float
   - After burn-in and After etching
   - Delamination
   - Core
1. Glass Transition Temperature
Temperature at which the polymer begins to soften...glassy state – denoted by Tg

Significant because the laminate see a series of "heat shocks" Soldering, Hot air leveling, Burn-in, and repair

2. Coefficient of Thermal Expansion [ppm/°C] \[ CTE \]

Materials expand on application of heat. A composite material expands differently in different directions

<table>
<thead>
<tr>
<th>Material</th>
<th>x-y axis</th>
<th>z axis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Epoxy-glass</td>
<td>15-18</td>
<td>45-60</td>
</tr>
<tr>
<td>Polyimide-glass 1</td>
<td>5-18</td>
<td>45-60</td>
</tr>
<tr>
<td>Epoxy-Aramid</td>
<td>6-8</td>
<td>95-110</td>
</tr>
</tbody>
</table>
3. Thermal Conductivity
   Generally, all Polymers are POOR conductors of heat
   Reinforcements are used to improve the Thermal conductivity

4. Flammability
   Should Extinguish within 50 seconds (FR4)

5. Water absorption
   Surface should not absorb water. Diffusion of water will create problems electrically.
1. Insulation Resistance - Surface and Volume
   - Surface Insulation Resistance: Meg-ohms
   - Volume Insulation Resistance: Ohm-cms

2. Dielectric constant or permittivity
   - Electrostatic energy storage capability of the material
   - Influence the signal travel speed - propagation delay
   - Lower the “dielectric constant” lower will be the propagation delay

3. Dielectric strength or breakdown voltage
   - Disruptive Voltage in “kilo-volts” measured between two points inch apart
Summary- Laminates

- Substrates are organic – rigid, flexible, and molded
- Standardization bodies – JEDEC, IPC, NEMA & Military
- Sub-standard laminates - affect the board quality
- Substrate selection - influences reliable performance
- Designer - freezes the laminate type and construction

* Bromine is banned material (laminates)
Board Fabrication Process

- Know the safety procedures before entering the lab/ work spot

- Right to Know about Materials Safety

- Read the Materials Safety Data Sheet

- Follow Clean Room work procedures

- Make sure fire fighting equipment is in place

- Make sure the nearest health centre/ security telephone numbers are made available to all personnel in the lab/ work spot
Working in a clean room environment - a short video

Working in a Clean Room Environment
BOARD PREPARATION or SURFACE PREPARATION
- Organic degreasing to remove oils, greases and stains from the surface of Cu to promote adhesion-use of organic solvents: TCE or IPA (isoo propyl alcohol)
- Acid cleaning- mild HCl
- Alkali cleaning- mild caustic solution
- Mechanical brushing-rolling brushes with Alumina impregnated
- Micro-etching- Ammonium per sulfate
- Washing with DI water (De ionized)
- Drying in controlled conditions

Surface preparation
Board preparation for imaging
Imaging

- Application of photoresist, dry or wet film depending on design requirement
- Light sensitive material, short storage life
- Cross-linking of polymeric material, requires initiator
- **Wet film**: Dip coating, Spin coating, Curtain coating, Meniscus coating
- **Dry film**: Vacuum laminator

- Advantages of dry film over wet film; vice-versa
  - Du Pont and Ciba among many others
  - PMMA, PV based, DQ (diazooquinones),
  - SU-8 etc (epoxy based), Novolac
  - Solvent: Organic or Aqueous based
Examples of imaging using a photoresist

Developed liquid resist (15μm) on 12" FR-4, #061499-7048A

23μm
27μm

20μm thick, 37.5μm thick
Dry film FR image on 12" FR-4 UTC

40μm
35μm

80μm thick, 57.5μm thick
Dry film FR-10047 on 12" FR-4 UTC

Fine lines

50μm pitch comb, liquid resist (15μm)
Developed image on 12" FR-4, #061499-7048A

Fig.: Dr Fuhan Liu, GTech
Photoresist

- Photoresist is an organic polymer which changes its chemical structure when exposed to ultraviolet light.
- It contains a light-sensitive substance whose properties allow image transfer onto a printed circuit board.
- There are two types of photoresist: positive and negative
  - A positive resist is a type of photoresist in which the portion of the photoresist that is exposed to light becomes soluble to the photoresist developer and the portion of the photoresist that is unexposed remains insoluble to the photoresist developer.
  - A negative resist is a type of photoresist in which the portion of the photoresist that is exposed to light becomes relatively insoluble to the photoresist developer. The unexposed portion of the photoresist is dissolved by the photoresist developer.
  - Use the right combination of negative or positive mask along with a negative or positive resist as the application may require.
Photoresist application and Patterning Circuit

1. **Substrate**
2. **Copper clad**
3. **Photoresist coated Cu**

- Use mask and expose to UV
- Pattern protected
- Etch away unwanted Cu