Laminate & Prepreg
Manufacturing
Manufacturing Technology Focus

Treating
- Gamma Gauges for Resin content control
- On line DCM’s, MMV’s, FTIR’s
- High Shear mixing equipment, Dedicated lines, Filtration systems

Lay up
- Sandwich copper concept, separate rooms.
- Controlled Clean room environment with Humidity and static control.

Press
- High temperature pressing capability

Finishing
- High Speed and precise finishing capability.

Manufacturing Focus
- Internal contamination Reduction - Controlled environment, Treating technology, handling and lay up technology.
- Prepreg Consistency - Resin content control, On Line cure monitoring, Redundancy with FTIR, Melt viscosity and Gelation
- Surface quality - Lay up Technology
- Controlled thickness.

Cost
- Productivity enhancement through lean manufacturing, Re engineered Processes

QTA
- Fast turn around capability through cycle time reduction, sophisticated scheduling and equipment capability
Material Building Blocks

**Glass**
- Glass fabric is available in different roll widths and thicknesses
- Some glass fabrics are different between North America, Asia Pacific and Europe
- Core constructions are different depending on the region and OEM spec.

**Resin**
- The resin is determined by what properties are needed to make a particular MLB design function. ie. Tg, Dk, Df etc.
- The resin must be compatible with the glass fabric
- The resin must be compatible with the copper foil

**Copper**
- Copper is designated by wt and foil type i.e. Reverse Treat ( RTF ), HTE, Double Treat or std ED copper foil
- The copper used must be able to achieve good peel strengths so the copper does not pull away from the glass and resin.
OEM designs are calling out the number of plies of glass to be used per core layer and even calling out the glass fabric style when controlled impedance is critical.

It is important that we understand the effect of the glass used in the construction of the core material we give to an OEM. A 2 ply construction vs. 1 ply will give you a different Dk and Df based on the retained resin % of the core.

When programs move from one Region to the other please be aware of the constructions used in the other Regions. For critical OEM’s and designs we need to try and keep the electrical properties of the material the same ie the same construction of core material

On the next slide you will see the different glass styles used in North America Asia Pacific and Europe.
Glass Fabric
# Glass Fabric

<table>
<thead>
<tr>
<th>Glass Style</th>
<th>Weave</th>
<th>Warp Count</th>
<th>Fill Count</th>
<th>Warp Yarn</th>
<th>Fill Yarn</th>
<th>Fabric Thickness inches</th>
<th>Fabric Thickness mm</th>
<th>Fabric Nominal Weight OSY</th>
<th>Fabric Nominal Weight g/m²</th>
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<tbody>
<tr>
<td>1067</td>
<td>Plain</td>
<td>70</td>
<td>70</td>
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## Fiberglass Yarn Nomenclature

- **1st Letter** E = E-glass (electrical grade)
- **2nd Letter** C = Continuous Filaments
- **3rd Letter** Filament Diameter D, E, DE, G
- **1st number** Yardage in one pound
- **2nd number** Number of strands in a yarn/strands plied or twisted
Woven Glass Fabric

106
Warp & Fill Count: 56 x 56 (ends/in)
Thickness: 0.0015” / 0.038 mm

1080
Warp & Fill Count: 60 x 47 (ends/in)
Thickness: 0.0025” / 0.064 mm

Photos courtesy of Isola R & D Laboratories
Woven Glass Fabric

1067
Warp & Fill Count: 70 x 70 (ends/in)
Thickness: 0.0013” / 0.032 mm

Photos courtesy of Isola R & D Laboratories

1086
Warp & Fill Count: 60 x 60 (ends/in)
Thickness: 0.002” / 0.050 mm
Woven Glass Fabric

2113
Warp & Fill Count: 60 x 56 (ends/in)
Thickness: 0.0029” / 0.074 mm

2313
Warp & Fill Count: 60 x 64 (ends/in)
Thickness: 0.0032” / 0.080 mm

Photos courtesy of Isola R & D Laboratories
Woven Glass Fabric

3070
Warp & Fill Count: 70 x 70 (ends/in)
Thickness: 0.0034” / 0.086 mm

3313
Warp & Fill Count: 61 x 62 (ends/in)
Thickness: 0.0032” / 0.081 mm

Photos courtesy of Isola R & D Laboratories
Woven Glass Fabric

**2116**
Warp & Fill Count: 60 x 58 (ends/in)
Thickness: 0.0038” / 0.097 mm

**1652**
Warp & Fill Count: 52 x 52 (ends/in)
Thickness: 0.0045” / 0.114 mm

Photos courtesy of Isola R & D Laboratories
Woven Glass Fabric

1506
Warp & Fill Count: 46 x 45 (ends/in)
Thickness: 0.0056” / 0.140 mm

7628
Warp & Fill Count: 44 x 32 (ends/in)
Thickness: 0.0068” / 0.173 mm

Photos courtesy of Isola R & D Laboratories
# Regional Woven Glass Fabric Styles

<table>
<thead>
<tr>
<th>North America</th>
<th>Asia-Pacific</th>
<th>Europe</th>
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<tbody>
<tr>
<td>106</td>
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<td>1652</td>
<td>7628</td>
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Isola has Global Std Constructions on the High Performance Materials
Multilayer Core Manufacturing

Sep. Plate
Copper
2 plies
B-Stage
Copper
Sep. plate
## Typical IS415 0.005” Core Constructions

<table>
<thead>
<tr>
<th>Core/ Construction</th>
<th>Positives</th>
<th>Negatives</th>
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<tbody>
<tr>
<td>0.005” Resin %</td>
<td></td>
<td></td>
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<tr>
<td>1 x 1652</td>
<td>Cost/ Thickness/ DS</td>
<td>Low Resin/ thick glass</td>
</tr>
<tr>
<td>106 / 2113</td>
<td>DS/ Std 2 ply</td>
<td>Most Expensive</td>
</tr>
<tr>
<td>2 x 1080</td>
<td>Low Cost</td>
<td>DS/ Thickness</td>
</tr>
<tr>
<td>1 x 2116</td>
<td>Low Cost</td>
<td>DS/ Thickness</td>
</tr>
</tbody>
</table>

Dk / Df differences based on retained resin %. The difference can be up to 14 %

- At 2 GHz  Dk on 42 % = 4.12  Df on 42 % = 0.016
- At 2 GHz  Dk on 56 % = 3.79  Df on 56 % = 0.0198

Critical that the right core thickness is used by the OEM/ Designer to meet the impedance criteria.
Grain Direction
Grain Direction

- 50” wide glass
- 50” x 38” untrimmed
- 48” x 36” trimmed
- oversized panels available

50” wide Glass - Fill Direction

Grain Direction or Warp Direction
Copper Foil
ED Copper Foil Manufacturing

- Copper is electroplated onto a rotating drum.
- Treatments are applied to:
  - Micro-roughen surface for adhesion
  - Plate barrier layer
  - Coat with anti-tarnish
Copper Foil Types

ED = standard shiny copper, copper tooth
HTE = High temp elongation shiny copper, copper tooth
RTF = reverse treat, low profile copper tooth
DT = double treat copper, no black oxide needed

- The RTF copper foils offer benefits to the fabricator during processing – more defined etched line, ability for thinner lines and lower copper tooth profile.

- VLP foils are used for better impedance control

- 95+ % of NA is RTF foil. Very small percentage = DT

- Thicker cores still use some HTE or ED foil.

Copper wt

18 micron = H oz
35 micron = 1 oz
70 micron = 2 oz

Heavier copper such as 3, 4 and 5 oz foil used for power supply designs or ground planes in MLB designs

5 and 6 oz Cu for Automotive 4 – L designs

12 oz Cu used for Automotive 2 – L designs
Electrodeposited Copper Foil

- ED Foil is “Industry Standard
- Many thicknesses available
  - ½, 1 and 2 ounce the most common
  - 3+ available
  - 9, 5, 3 micron

<table>
<thead>
<tr>
<th>Grade</th>
<th>Foil Description</th>
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<tbody>
<tr>
<td>1</td>
<td>Standard Electrodeposited</td>
</tr>
<tr>
<td>2</td>
<td>High Ductility Electrodeposited</td>
</tr>
<tr>
<td>3</td>
<td>High Temperature Elongation Electrodeposited</td>
</tr>
<tr>
<td>4</td>
<td>Annealed Electrodeposited</td>
</tr>
<tr>
<td>5</td>
<td>As Rolled-Wrought</td>
</tr>
<tr>
<td>6</td>
<td>Light Cold Rolled-Wrought</td>
</tr>
<tr>
<td>7</td>
<td>Annealed-Wrought</td>
</tr>
<tr>
<td>8</td>
<td>As Rolled-Wrought Low-Temperature Annealable</td>
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<table>
<thead>
<tr>
<th>Foil Profile Type</th>
<th>Max. Foil Profile (Microns)</th>
<th>Max. Foil Profile (µ Inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>S – Standard</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>L – Low Profile</td>
<td>10.2</td>
<td>400</td>
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<tr>
<td>V – Very Low Profile</td>
<td>5.1</td>
<td>200</td>
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<tr>
<td>X – No Treatment or Roughness</td>
<td>N/A</td>
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</table>

<table>
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<tr>
<th>Foil Designator</th>
<th>Common Industry Terminology</th>
<th>Area Weight (g/m²)</th>
<th>Nominal Thickness (µm)</th>
<th>Area Weight (oz/ft²)</th>
<th>Area Weight (g/254 in²)</th>
<th>Nominal Thickness (mils)</th>
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<tr>
<td>E</td>
<td>5 µm</td>
<td>45.1</td>
<td>5.0</td>
<td>0.148</td>
<td>7.4</td>
<td>0.20</td>
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<td>Q</td>
<td>9 µm</td>
<td>75.9</td>
<td>9.0</td>
<td>0.249</td>
<td>12.5</td>
<td>0.34</td>
</tr>
<tr>
<td>T</td>
<td>12 µm</td>
<td>106.8</td>
<td>12.0</td>
<td>0.350</td>
<td>17.5</td>
<td>0.47</td>
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<td>H</td>
<td>½ oz</td>
<td>152.5</td>
<td>17.2</td>
<td>0.500</td>
<td>25.0</td>
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<tr>
<td>M</td>
<td>¾ oz</td>
<td>228.8</td>
<td>25.7</td>
<td>0.750</td>
<td>37.5</td>
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<td>1</td>
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<td>3</td>
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Copper Surface Profiles

• Matte Side Surface Profile

Matte Side of Standard Grade 1 Foil  Matte Side of Low Profile Grade 1 Foil

• Standard vs Drum Side Treated Foil (DSTFoil)

Laminate With Standard Copper Foil  Laminate With DSTFoil® Copper Foil
DSTF Process Introduction

Grain Structure and Surface Profile

III (HTE)  Super-HTE  VLP

※After heated at 180℃, 1hr

1oz Foil
DSTF Process Introduction

DSTFoil® Comparison to Standard Copper Foil

- Standard Copper
- Bonding Treatment
- DSTFoil®
- Bonding Treatment
DSTF Process Introduction

Standard Foil Clad Laminate

DSTFoil ® Clad Laminate

- Copper
- Bonding Treatment
- Core
- Copper
Definitions
The Electromagnetic Spectrum employed for RF & Microwave applications

- Shortwave radio
- Mobile Radio
- VHF TV Begins
- FM Broadcast Radio
- Mobile Radio
- VHF TV Begins
- UHF TV ends
- Cellular phone
- GPS
- PCS
- Bluetooth
- Wireless LAN
- DBS
- Remote Sensing

HF: 3 MHz – 30 MHz
VHF: 10 MHz – 30 MHz
UHF: 100 MHz – 300 MHz
RF: 300 MHz – 1 GHz
MW: 1 GHz – 3 GHz
MMW: 3 GHz – 30 GHz

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Definitions

$T_G$ – Glass Transition Temperature; *The temperature at which the resin changes from a glass-like state to an amorphous state changing its mechanical behavior, i.e. expansion rate*

DSC – Differential Scanning Calorimetry; *A measurement technique used to characterize the glass transition temperature of a resin by measuring the change in heat given off the resin.*

TMA – Thermal Mechanical Analysis; *A measurement technique used to characterize the glass transition temperature of a resin by measuring the changing in thermal expansion of a resin as a function of temperature.*

DMA – Dynamic Mechanical Testing; *A measurement technique used to characterize the glass transition temperature of a resin by measuring the change in modulus of a resin as a function of temperature.*

$T_D$ – Decomposition Temperature; *The temperature at which the resin begins to decompose, measured by a weight change the resin sample.*
TGA – Thermo-Gravimetric Analysis; A measurement technique used to characterize the decomposition temperature of a resin by measuring the change in weight as a function of temperature.

CTE – Coefficient of Thermal Expansion; The rate of expansion of a laminate as a function of temperature change. Typically reported as PPM/°C or %.

T<sub>260</sub> – Time-to-Delamination @ 260°C; A measurement conducted on the TMA apparatus in order to determine a laminate’s resistance to Delamination at 260°C. Delamination is defined as an irreversible expansion in the z-axis. Measurements are noted in minutes at 260 °C before failure.

T<sub>288</sub> – Time-to-Delamination @ 288°C; A measurement conducted on the TMA apparatus in order to determine a laminate’s resistance to Delamination at 288°C. Delamination is defined as an irreversible expansion in the z-axis. Measurements are noted in minutes at 288 °C before failure.

Dk – Permittivity, Relative Dielectric Constant; The property of a material that impedes the transmission of an electromagnetic wave. The lower the relative dielectric constant, the closer the performance of the material to that of air. This property is critical to matching the impedance requirements of certain transmission lines.
**Df – Loss Tangent;** The property of a material that describes how much of the energy transmitted is absorbed by the material. The greater the loss tangent, the larger the energy absorption into the material. This property directly impacts the signal attenuation at high speeds.

**Peel Strength;** This measurement is taken to evaluate the adhesion of the resin to the copper cladding, in units of lb/in or N/m. Measurements are taken after samples have been conditioned in the following manner: as received, after thermal stress, and after chemical processing.

**Thermal Stress;** This measurement is taken to evaluate the thermal integrity of laminates after short-term exposure to solder, 10 seconds at 550 °F (288 °C). The samples are evaluated for evidence of blisters and delamination.
TCT – Thermal Cycling Test; this type of reliability test is conducted in order to evaluate a PCB’s resistance to plated-thru-hole failures when exposed to repeated temperatures extremes. Factors in this test that vary from OEM-to-OEM include temperature ranges, time at given temperatures, and medium used to heat and cool the PCB (i.e. liquid or air).

IST – Interconnect Stress Test; an accelerated thermal cycling test that utilizes DC current to heat the PTH and uses forced air to cool the PTH of a PCB coupon. The benefits of using IST in place of conventional TCT tests include lower cost, failure detection and results within days.

CAF – Conductive Anodic Filament Growth Failure; a PCB reliability issue related to the growth of copper containing filament along the resin-to-glass interface
Isola

RoHS

Halogen Free
RoHS Compliancy – Products that are RoHS compliant do not contain the 6 chemical substances listed on the following slide. These substances are not to be used in the base chemistry of laminates or prepregs.

A RoHS compliant resin system does not mean that it is Lead Free Assembly Compatible at 260°C.

ALL Isola Products are RoHS Compliant
EU RoHS Compliance

- Restriction of Hazardous Substances
- Legislation bans the following Six substances for shipment to EU countries effective July 1 -2006
  - Lead (Pb)
  - Mercury (Hg)
  - Hexavalent Chromium (Cr\textsuperscript{6+})
  - Polybrominated biphenyl (PBB)
  - Polybrominated diphenyl ether (PBDE)
  - Cadmium (Cd)

- High End Networking companies exempt until 2010 and beyond

Max Conc. By Wt. < 0.1 %
- - Max Conc. By Wt. < 0.01 %